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JOHN-STREET, ADELPHI, LONDON, W.C.

PRESIDENT—H.R.H. THE PRINCE OF WALES, K.G.

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ON

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HELD

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TABLE OF CONTENTS.

Suggestions for dividing England and Wales into Districts for the Supply of Pure Water ....1—71
Essay by Frederick Toplis 3
,, ,, Joseph Lucas 16
,, ,, A. T. Atchison 27
,, ,, W. H. Penning 35
,, ,, D. T. Ansted 43
,, ,, S. B. Goslin 65

Papers ....72—157

Methods of Securing a Sufficient Supply of Pure Water ....72—113
Brown (A. H.), M.P., "The Incidence of Rating for Sanitary Purposes in Rural Districts 72
Conder (Francis B.), C.E., "On the Utilisation of the Water Supply of England"...... 74
Wheeler (W. H.), M.Inst.C.E., "The Water Supply of Rural Districts" 78
Clutterbuck (Rev. James C.), "The Water Supply of Large Towns" 84
De Rance (C. E.), F.G.S., "Pervious Rocks of England and Wales" 85
Hull (Prof. Edward), LL.D., F.R.S., "On the Underground Water Supply of Villages, Hamlets, and Country Parishes, of the Central and Eastern Counties of England" 86
Lucas (Joseph), F.G.S., "Watershed Lines; Subterranean Water-ridges" 91
Prestwich (Joseph), F.R.S., "National Water Supply" 93
Ansted (Prof. D. T.), M.A., F.R.S., "River Conservancy" 94
Denison (Ven. Archdeacon G. A.), "Supply and Storage of Pure Drinking Water, East Brent, Somerset" 97
Dillon (James), "On the Effects of Under and Arterial Drainage on Rivers and Floods" .. 97
Hawkshaw (J. Clarke), "River Conservancy, Illustrated by Drainage Admistration in Holland" 101
Lynam (James), C.E., "The Sanitary State of the Valley of the River Shannon referred to Bad Regulating Weirs" 105
Smyth (John), jun., C.E., "On the Water Supply of the Upper Bann River, Ireland, and the Amount of Rainfall Utilised" 107
Denton (J. Bailey), "National Water Supply; Domestic Filtration of Water Conserved in Tanks and Cisterns" 110
Foote (G.), Medical Officer of Health, "The Water Supply of Kingston and Neighbourhood" 111
Slagg (Charles), C.E., "Suggestions of a State Record of the Surplus Water Flowing from High and Uncultivated Lands" 112
Sutcliff (Robert), "Abyssinian Tube Wells" .. 113

Evils of Impurity, and Consequent Connection of the Question of Water Supply and Sewage ....116—119
Brown (John), L.R.C.P., "Remarks on some of the Diseases due to Sewer Gas Poisoning" 116
Thorne (R. Thorne), M.D., "The Recent Outbreak of Enteric Fever at Caterham" 117
Hart (Ernest), "Epidemics Produced by Polluted Water Supply" 119

Methods of Sewage, &c. ....123—155
Cole (Sir Henry), K.C.B., "Progress with Sewage since the First Congress of the Society of Arts in 1876, submitted to the Fourth Congress in 1879" 123
Cresswell (C. N.), "The Thames and its Tributaries" 127
Chadwick (Edwin), C.B., "Course of Inquiry as to Works of Sanitation, and as to their Expense and Results" 130
Latham (Baldwin), C.E., "Works of Sewage and Sewage Disposal — Croydon Sanitary Authority" 136
Cole (Granville), Ph.D., "Some Experiences of Sewage Effluents, and Burning Sludge into Cement" 137
Hillé (F.), "Ten Years' Practical Experience in Sewage Treatment" 139
Jones (Lieut.-Col. Alfred S.), V.C., "Sewage Disposal at Wrexham" 141
Masters (Henry), "The Double Check System of House Drainage" 144
Banner (E. G.), "House Drainage." The Banner System of House Sanitation 147
Morrell (Conyers), "Cinder-sifting Ash-closets" 150
Sturge (W. Allen), M.D., "Sewage Irrigation in Paris" 151
Winton (John G.), "The Ventilation of Sewers" 153
Seaton (Edward), M.D., "The Substitution of the Pail System for the Privy Midden System in Nottingham, and its Effects in Reducing the Mortality and Sickness from Enteric and Continued Fevers" 155

Discussion ....158—186

Returns on Sewage Farms ....187—188

Additions to "Notes on Previous Enquiries" (1878) ....189—205

Catalogue of Exhibition ....206—208

SUGGESTIONS

FOR DIVIDING ENGLAND AND WALES INTO DISTRICTS, FOR THE

SUPPLY OF PURE WATER

TO THE TOWNS AND VILLAGES IN EACH DISTRICT.

THE Council of the Society offered One Gold and Three Silver Medals for the best suggestions for the above purposes.

The following Committee was appointed to adjudicate upon the papers sent in in response to the offer:—

Professor F. A. Abel, C.B., F.R.S.	Professor Prestwich, F.R.S.
John Evans, F.R.S.	Professor Ramsay, F.R.S.
Captain Douglas Galton, C.B., F.R.S.	G. J. Symons, F.R.S.

Report of Committee presented to the Council Meeting, held on May 12th.

"The Committee have to report as follows:—They have held three meetings, and have carefully considered the suggestions sent in in answer to the Society's offer of prizes. Twelve papers were sent in; of these the Committee selected seven as being worth printing for circulation at the Conference on Water Supply, &c.

"They are of opinion that none of the essays sent in are worthy of a Gold Medal, but they have selected two which they think worthy of Silver Medals. These are—1st, the essay bearing the motto, 'Better Late than Never;' and, 2nd, the essay bearing the motto, 'Gutta cavat lapidem, non vi, sed sæpe cadendo.'

"Having made these awards, they proceeded to open the envelopes containing the names of the competitors, and they found that the essay bearing the motto, 'Better Late than Never,' was sent in by Mr. Frederick Toplis, and that bearing the motto, 'Gutta cavat lapidem,' &c., was sent in by Mr. Joseph Lucas. They also opened the envelopes containing the names of the other five competitors, and instructed the Secretary to write to each of them, asking whether he would wish his essay to be printed with his name to it or merely under its motto.

"The Committee think that there are many points of merit in all the seven essays, but they are unanimously of opinion that the two they have selected for awards are much superior to any of the rest."

The following were the conditions of the offer:—

1. The Council of the Society of Arts offers One Gold and Three Silver Medals for the best suggestions, founded upon evidence already published, for dividing England and Wales into districts, for the supply of pure water to the towns and villages in each district.

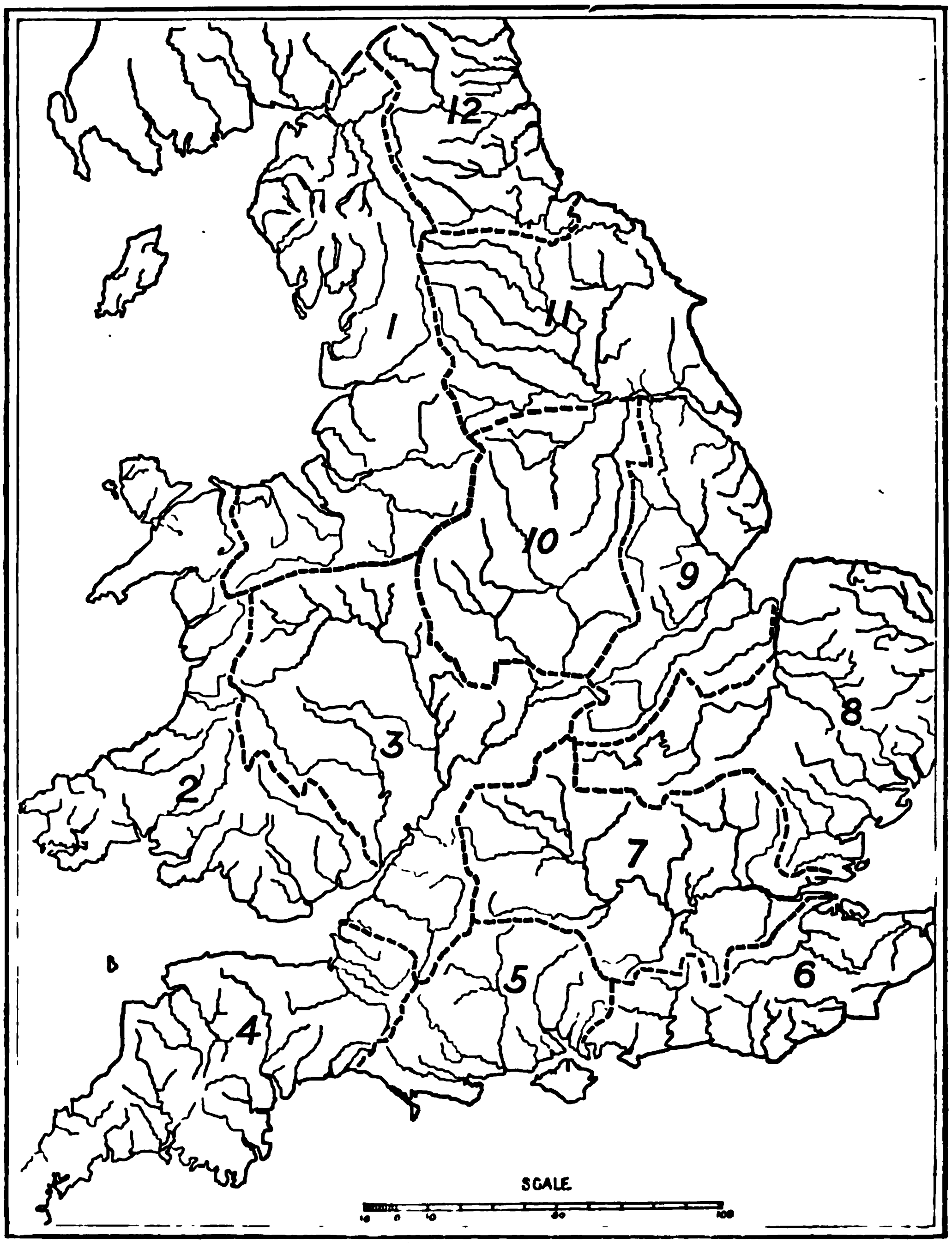
2. The districts should be laid out on a skeleton map scale, which can be obtained from Mr. Stanford, 55, Charing-cross, price 6d. each.

3. The average rainfall in the district should be stated; also the population of the district, and its geology.

4. The suggestions should be written on foolscap, half-margin, and sent, accompanied by maps, under cypher, to the Secretary of the Society of Arts, on or before the 26th day of April, 1879.

5. The maps will be exhibited, and the suggestions will be discussed at the Conference on National Water Supply, to be held at the Society's Rooms, in May.

6. The Council will invite the assistance of eminent authorities to recommend the competitors worthy to receive the Prizes; but the Prizes will be withheld if the suggestions made do not appear to the Judges to be of sufficient merit.



Map of Districts Proposed by Frederick Toplis.

SUGGESTIONS,

FOUNDED UPON EVIDENCE ALREADY PUBLISHED, FOR DIVIDING ENGLAND AND WALES INTO WATER-SHED DISTRICTS, FOR THE SUPPLY OF PURE WATER TO THE TOWNS AND VILLAGES IN EACH DISTRICT.

ESSAY BY FREDERICK TOPLIS.

Motto—"Better late than never."

AWARDED A SILVER MEDAL.

If it were possible to start completely *de novo*, it would be a comparatively easy matter to arrange a system of water supply for England and Wales, which would provide a reasonably pure water for all existing towns and villages, and which would be capable of extension as fresh villages sprang up, and as towns grew and expanded. No scheme, however, can be considered satisfactory which does not take into account the large amount of capital already expended on water-works, and does not utilise, as far as possible, all existing works for water supply. There are enthusiastic reformers among us who say that everything, or almost everything, done up to this time is wrong; that the water supplied, for the most part, is impure and unfit for consumption; and that we must ignore all that has been as yet done, and make a fresh start. One would have us get all our water from the chalk formation, and assures us that there is an inexhaustible supply there, sufficient to provide every town and village in England and Wales with an unlimited amount of the purest water. Another would persuade us that this water is too hard to be fit either for use by the manufacturer or for domestic purposes, and that the wells already sunk in the chalk are slowly but surely draining it dry, and that we ought to go for our supply to the upper courses of the rivers and streams. A third, again, has a preference for gravitation schemes, as they are called, and would construct enormous reservoirs in the mountainous districts of the north-west of England and of Wales, and supply the whole country from these.

The Royal Commissioners on Water Supply, in their report issued in 1869, went very fully into the question of the water supply to London, but declined to go into the larger questions of the supply to provincial towns, or of the gathering grounds in various parts of the country generally available for water supply, giving as their reason that the inquiry must be one of great magnitude, involving a large amount of statistical and topographical investigation extending over the whole kingdom. The Commissioners, however, state in decided terms their opinion that no town or district should be allowed to appropriate a source of supply which naturally belongs to a town or district nearer to such source, unless under special circumstances which justify the appropriation; that when any town or district is supplied by a line of conduit from a distance, provision ought to be made for the supply of all places along such line; and that, in the introduction of any provincial water Bill, attention should be drawn to the practicability of making the measure applicable to as extensive a district as possible. These recommendations ought to form the basis of the future policy of all water legislation, and for the proper carrying out of them the following conditions seem to the author to be absolutely necessary.

1. That the country should be mapped out into watershed districts, each containing one or more complete river basins, and that a body of commissioners should be appointed to each district. These commissioners should be nominated by Government with the sanction of Parliament; they should be men not connected with the district by personal residence, nor by having property or business in the district, and their appointment should be for life, or at any rate for a long term of years, otherwise they will not take sufficient interest in their work to acquire a thorough knowledge of it. A man appointed to a post for a year or two rarely cares to go through the drudgery necessary to make himself acquainted with all the petty details connected with it.

2. That these Commissioners should be assisted by competent legal and engineering advisers. They should have a permanent engineer, at a salary sufficient to secure a man of considerable experience in hydraulic engineering: and there should be a consulting engineer chosen from the first rank of engineers engaged in this class of work. It may, however, be left undecided for the present whether each set of commissioners should have its own consulting engineer, or whether two or more districts should be grouped together, or whether there should be only one, or perhaps two, consulting engineers for the whole of England and Wales.

3. That these Commissioners should have charge, not only of the waterworks in their district, but also of the rivers and other watercourses, and, in

fact, that every drop of water falling in their district should be more or less under their control, from the time it falls on the land until it reaches the sea. All existing Commissioners for river improvements, &c., must be abolished, and their authority merged in that of the new Commissioners, whose duty it would henceforth be to initiate and carry out works for the improvement of river navigation, for the prevention of floods, &c.

4. The Commissioners must have power to acquire all existing waterworks, and, if necessary, all canals, &c. With regard to canals, it will not, perhaps, be advisable that the Commissioners should acquire them except when, owing to the scarcity of water in a district and to the smallness of traffic on the canals, it may be considered advisable that they should be closed.

There are, no doubt, cases where the canals are fed with water which might be used as a source of supply to towns and villages, and there may even be cases where the canal itself might be used to convey the water to the towns, care being taken to cleanse its bed, to stop all pollution of the water for the future, and to discontinue the traffic. In other cases, again, canals might be used as flood channels, the locks being removed, and weirs, or sluice gates, substituted. Many of the canals have been purchased by the railway companies, solely for the purpose of preventing competition, and there would probably be little difficulty in acquiring these from the railway companies; but, in all cases where the abundance of water in the district, and the largeness of traffic on a canal, justify its being kept for traffic, it would not be desirable that the Commissioners should acquire it, but only that they should have control over it, to prevent the waste of water, or the increase of floods, or the pollution of rivers by the introduction of impure water from the canal.

The time is drawing near when it will be found absolutely necessary to appoint a Minister of Health, with an adequate staff, and he should have control, not only over the above suggested Commissioners, but also over all sewage authorities, and over all manufactories which pollute the air, and, in short, it should be in his charge that neither the water nor the air of the kingdom should be unnecessarily polluted. No doubt he would have other duties which, however, do not concern this paper. It is not intended that the Commissioners of Water Supply, which it is suggested should be appointed, should have charge of the sewerage arrangements of the districts. These may remain, as far as the present paper is concerned, under the existing authorities, although, no doubt, it will be desirable that a similar scheme to the present should be arranged for the creation of Commissioners of Sewage, and it will simplify matters if the jurisdictions of the two sets of Commissioners are conterminous. It must, however, be urged that it is advisable that these two bodies, the one charged with keeping all the water in the district as pure as possible; and, the other, with purifying as far as possible that portion of the water of the of the district which has necessarily been polluted, should be quite distinct, and that their engineers and consulting engineers should be different. It will the author thinks, be admitted that the Commissioners of Water Supply will be much more likely to guard the rivers jealously from pollution if they have not themselves the task of purifying the polluted waters of the sewers.

Both sets of Commissioners would be under the proposed Minister of Health, who would decide any controversies between them. It would be wise not to continue the piece-meal legislation which has hitherto prevailed in England in reference to water supply, and instead of, as some may be disposed to suggest, creating a set of Commissioners in one district where the question of water supply is most pressing, and afterwards enlarging the district and then creating another, and so on, it would be wise to at once map out England and Wales into districts. There has been, it is believed, a great deal of information collected by the Ordnance and Geological Survey Departments in connection with the existing and possible water supply, and it seems reasonable to expect that, if a Royal Commission were appointed to collect evidence and draw up a scheme, its labours would be finished in a short time. This Commission would, of course, include those Government officials whose duties have enabled them to gain information on the subject of water supply—such as the Directors of the Ordnance and Geological Surveys, and the engineers of the Local Government Board; and also several independent engineers of eminence in this branch of the profession.

The duties of this Commission would consist rather in arranging and utilising the vast store of information already collected by previous Royal Commissions, by the Survey Departments, and by private engineers, in the course of their practice, than in making fresh analyses or taking fresh evidence. The work of the Commission might be brought to a close at the end of one, or at the utmost two years, and the evidence it would collect would be of great service to the Commissioners afterwards appointed.

The next stage would be for Government to introduce a Bill to create the districts and appoint Commissioners, and there would be much less opposition if one general scheme were brought in, than if each district were taken separately. The Commissioners would choose their engineers, the Government appointing the consulting engineers. On the death or retirement of any of the Commissioners, the Government would appoint a successor.

The Commissioners should be instructed to proceed gradually, first acquiring a thorough knowledge of their district; then, proceeding to check all pollutions, to provide a water supply where none exists, to extend existing supplies, to improve the rivers, &c. They should be authorised to levy a double rate; one for the supply of water, it being understood that where a good supply at present exists the rates are in no case to be increased; and the other for the improvement of rivers and prevention of floods. It has hitherto been usual to levy rates for the prevention of floods only on the lands liable to be flooded; but the opinion is gradually spreading that, as the waters from the high lands contribute to the floods, and, as the water is poured off the lands much more rapidly than formerly, owing to the improved drainage, so it is only just that the high lands should contribute their quota to the rates, though not in as large a proportion as the low lands. It is estimated that, if this scheme were carried out, it could be got into working order within five years of the present time, and that although there would still be much to be done, an end would have been put to the present state of confusion, and to the waste of money in Parliamentary contests between different towns, or even between different parties in the same town.

Now to consider in more detail the duties of the proposed Water Commissioners. They may be divided into:—

1st. Providing against the pollution of all springs, wells, water-courses, streams, lakes, and rivers; 2nd. Providing against floods, and storing water so as to maintain a sufficient flow in the rivers, in dry seasons, for the purposes of navigation, for water power, irrigation, &c.; and 3rd. Providing a sufficient water supply of reasonable purity to all towns and villages in the district. These duties are taken in this order merely for convenience, not as in any way showing their relative importance.

1. *Providing against Pollution.*—This has hitherto been a very great difficulty, owing to the divided interests in the different river basins, to the persons charged with the protection of the rivers being local men, who are often themselves guilty of polluting them, and to the legal difficulties and expense. Some alteration would, of course, have to be made in the mode of proceeding against offenders. but it is out of the scope of the present paper to suggest what it should be. It may, the author thinks, be hoped that, under the new authorities, more success would be obtained than has yet been, as the whole of each water-shed would be under one charge, and the Commissioners would have no local interests to prejudice and hinder them in the fulfilment of their duties. The source of pollution may be divided into manufacturing, sewage, and agricultural. The question of the pollution of rivers was very fully discussed at the Conference at the Society of Arts, in December, 1874. Mr, John Thom, a calico printer, in a paper read at the Conference, stated that by purifying the waste water from his works, and preventing the pollution of the stream, he got a good per-centage on all the money spent, after having paid all working expenses. In many other manufactures the purification of the waste water would give an actual profit.

The removal of all sewage pollution from rivers is only a question of time. Many towns have already carried out efficient schemes of purification. Irrigation seems to have been the most successful plan, and might be more fully carried out if Commissioners of Sewage were appointed in each district, as suggested.

Agricultural pollution must always remain, and on this account, stream or river water, when there is any considerable extent of cultivated land in the basin draining into the river, can never be a desirable source of water supply for domestic purposes.

2. *Providing against Floods and Storming Water.*—This again, has, up to the present time, been very inefficiently performed, and, in fact, many of the works carried out for the improvement of rivers have been worse than useless. The River Nene may be taken as illustrating two great difficulties which at present lie in the way of all improvements. One, that a river basin is often under the charge of several distinct authorities; thus the main channel of the Nene is under five or more different authorities, besides which there are numerous others having jurisdiction over the banks, the washes, &c. The other, that one engineer after another is called upon to report on the state of a river, and each one thinks it necessary to differ more or less from his predecessors in his proposed works. About ten different reports on the River Nene have been made by eminent engineers since the beginning of this century, but the works proposed have either not been carried out at all, or else in a fragmentary and imperfect manner; and this river is still in a most unsatisfactory state.

The creation of one controlling authority in a river basin, with a permanent engineer, would, the author thinks, greatly facilitate the improvement of the river.

The Rivers Conservancy Bill, brought before Parliament this session, would, if passed. be an advance in the right direction, but there are several objections to it. The Conservancy Boards are not to be appointed at once over the whole kingdom, or even for the most important rivers, but the proposal to appoint a Board for any river is to originate with the landowners of the district. Another objection is, that a considerable proportion, if not the whole, of the members of the Board, are to be landowners of the district. The Thames and Lee are excluded from the Bill. Water-works and canals are not to be interfered with. It is doubtful whether, if this Bill were passed in its present form, the conservators would have full power to deal with all existing obstructions in rivers. Some of the authorities connected with the Nene and the Ouse, two of the rivers which most urgently require to be dealt with, have already protested against this Bill.

3. *Providing a Water Supply.*—This may be considered the most important of the duties of the Commissioners. They are to have power to acquire all existing water works, but need not acquire them if they do not think it necessary. In those places where the existing authorities are giving a good supply to their district from works in the district itself, there would seem to be no advantage in interfering with them. But in other cases, where water is brought from a long distance to a town, while places situated near this source of supply are very badly off for water, the Commissioners would take the works in hand, and enlarge them so as to afford a sufficient supply for the whole neighbourhood. In many cases now, towns fetch their water from a long distance, when abundant supplies of equally good or better water are near at hand. In others, they are content with impure water obtained in their neighbourhood, while, by combining with two or three adjoining places, they could bring pure water from a distant source with little increase of cost. Instances are given in the third report on Underground Waters, of the Committee appointed by the British Association, of places obtaining Acts to impound surface water from cultivated ground, when they could get an almost inexhaustible supply of pure water from shafts in the new red sandstone and permian. All these mistakes could be avoided, if there were some central body in a large district having power to

acquire all requisite information, and to carry out all works necessary.

Before proceeding to describe in detail the districts into which it is suggested England and Wales should be divided, it will be as well to make a few remarks touching the quality of water desirable, the quantity necessary, and the quantity available.

The Quality of Water Desirable.—A great amount of information is contained in the 6th Report of the Rivers Pollution Commissioners, on the subject of the relative purity of the water from different sources; and the waters classified as wholesome are, first, spring water; secondly, deep well water; and, thirdly, upland surface water. The proposed Commissioners would, in selecting the best available water in each district, of course have some regard to the relative cost of the different supplies, and would not go to an immense expense to provide a first-class water (to use a convenient expression), when a second-class one could be obtained at a moderate cost; provided always that this second-class water is sufficiently wholesome and palatable.

The upland surface water, though not considered as wholesome as the deep well or spring water, is, however, generally softer, and is therefore more suitable for the manufacturing towns; and, although hard water can, as the Rivers Pollution Commissioners frequently state in their Report, be softened by Dr. Clark's process, yet this process must always cause considerable trouble and expense. Provided the upland water is collected from ground not cultivated, and that every care is taken to keep it free from pollution after it has been collected, there need not, the author thinks, be any hesitation in using it for domestic as well as for manufacturing purposes. Great difference of opinion exists among engineers and other experts, as to the purifying effect of the exposure to the atmosphere of a polluted stream, some thinking that, if sewage be poured into a river, the water, after flowing seven miles, will be as pure as it is above the source of pollution; others, that no appreciable purification would be effected; but most, if not all, will agree that water taken from a stream polluted by sewage at any distance, no matter how great, below the entrance of the sewage, is not desirable for domestic purposes; and considering the vast quantities of pure water hitherto unutilised that exist throughout the kingdom, it may be assumed that it only requires the creation of some central authorities, such as the suggested Water Commissioners, to insure the abandonment of all such polluted sources. The method adopted by the Rivers Pollution Commissioners of estimating previous sewage contamination is, the author thinks, an inconvenient and a misleading one.

The protection of the underground waters from pollution is a point which has hitherto been entirely neglected, but which urgently requires attention. The custom prevalent in many parts of the country, of pouring sewage into cesspools in permeable strata, or into what are known as swallow holes, is one which it will soon be found necessary to put a stop to.

The Quantity of Water Necessary.—The quantity actually supplied varies in different towns from 10 to 50, or even 100 gallons per head per day, but there is often a considerable waste. The quantity used in cottages is sometimes as low as two gallons per head, when the water has to be fetched, or five gallons when there is a supply close to the cottage. In larger houses, from 10 to 20 gallons per head is used. The average consumption of the manufacturing towns of Lancashire and Yorkshire has been stated by Mr. Bateman to be from 16 to 20 or 21 gallons for all purposes.

Experiments made show that not more than 10 or 11 gallons per head are actually used for domestic purposes, and the majority of the evidence collected on this subject seems to prove that 20 gallons, or at the most 25 gallons, per head per day, ought to be enough for all purposes.

The constant system of supply, properly carried out, is greatly preferable to the intermittent, and will soon, no doubt, become universal. Its introduction has in many towns been attended with a decrease in the quantity supplied, but this does not prove that less is usefully used, if the expression might be allowed, with the constant system than with the intermittent system. The reason for the decreased supply is simply that more care is generally taken to inspect the water-mains and the fittings in the houses, and to see that there is no waste of water. Such, however, is not always the case, as for instance, in London, where the water companies have in some parts introduced the constant system without any alterations being made in the fittings, the result being that there are cisterns overflowing day and night for weeks together, saturating the soil round the houses. It must be remembered that, while the supply for domestic purposes ought to be sufficient, any waste of water is a disadvantage to the householder and to the community. Under a properly managed system, the rates, where 25 gallons per day is supplied, ought to be less than where the supply is 50 gallons; and if in the latter case half is wasted, it is certainly not true economy to provide 50 gallons per head per day. Again, if the water running to waste enters the sewers, it has in many cases to be pumped up again; and if the sewage is used for irrigation, it is unnecessarily diluted by the waste water, and thus rendered less valuable. If the waste water does not enter the sewer, but penetrates the soil, it produces dampness, leading to discomfort and disease.

The use of meters for domestic as well as for manufacturing supply is sometimes advocated, but seems to the author unnecessary and unadvisable. If there were a proper system of house inspection, and if the inhabitants in a district were made to understand that waste of water would cause increase of cost of supply, and, therefore, increased rates, meters would be unnecessary; and if introduced, might often lead to an undesirable stinting of the water used in a household. The author, in his calculations, has assumed 25 gallons per head per day as the supply required, but thinks that it would be found that 20 gallons would be amply sufficient. He wishes to point out, however, that a much larger quantity than 25 gallons per head of the present population is available in each district. Assuming the population of England and Wales, when this scheme is put in operation, to be 27 millions, the quantity required will be 675 million gallons per day; and when this population has doubled, the quantity required at the rate of

25 gallons per head per day, will be 1,350 million gallons per day or 492,750 million gallons, say 500,000 million gallons, per annum.

Quantity of Water Available.

The average rainfall throughout England and Wales is generally stated at 32 inches per annum, giving a total fall in the year of more than 27,000,000 million gallons; of this, the quantity given above, as required for a population of 54 millions, is less than 2 per cent. The direct collection of rain by each household for its own consumption has been advocated, but can only be carried out in country districts; and even there rain water could scarcely be classed as wholesome or palatable, as is shown by the analyses made for the Rivers Pollution Commissioners. The author thinks, however, that for the use of farming stock and agricultural machinery, rain water might and should be collected, and has, therefore, made no allowance for these purposes in estimating the quantity of water required per annum in England and Wales.

In the mountainous districts of the North-west of England, and of Wales, the rainfall is greatly in excess of the average, and, as the strata are impermeable, a large proportion of it runs off into the rivers and lakes; and the greater part of this water could be utilised, either by making impounding reservoirs, or by drawing off the water from the existing lakes.

In the central part of England, where the ground is of less elevation, and the rainfall not above the average, there is a very large area covered by the trias or new red sandstone formation. The Rivers Pollution Commissioners, referring to this, say that there is every reason to believe that vast quantities of hitherto unutilised water of most excellent quality is to be had, at moderate expense, from this very extensive geological formation. The committee appointed by the British Association state, in their second report, that "the area of new red sandstone is not less than 10,000 square miles in England and Wales, with an average rainfall of 30 in., of which never less than 10 in. percolates into the ground, which would give an absorption of 143,336,000 gallons per square mile per annum." This, over an area of 10,000 square miles, would give 1,433,360 million gallons, which is nearly three times the whole quantity that will be required for England and Wales when the population has doubled. In their third report, in 1877, the committee state that "there is an available daily supply from the new red sandstone and permian of England of not less than 3,600 million gallons per day, remarkably free from organic impurity."

Further to the east is a band of oolitic strata stretching from the north-east of Yorkshire to the south of Dorsetshire. The Rivers Pollution Commissioners say with reference to this formation, that "the oolites contain vast volumes of magnificent water stored in their pores and fissures;" and again that "the oolites absorb immense quantities of rain water," and that "it cannot be doubted that a considerable proportion of this could be secured for domestic supply in its pristine condition of purity."

Further east again are the greensands and the chalk, which contain large bodies of water. In the fourth report of the Committee of the British Association it is stated that there are 26,687 square miles of permian, trias, oolite, Hastings sand, greensand, and chalk, yielding subterranean waters. That "probably four-fifths of this area would yield unpolluted water, and would receive not less than from 10 to 15 inches annually, or a quantity, if six inches only were yielded in wells, of 240,000 gallons per day per square mile of surface, and in many districts double this, giving a total in England and Wales far in excess of that required for drinking and manufacturing purposes." 240,000 gallons per square mile over an area of four-fifths of 26,687 square miles, or 21,350 square miles, will give more than 5,000 million gallons per day. The quantity required for a population of 54 millions is given above, as 1,350 million gallons per day.

Further reference will be made to the available supply in giving the details of each district, but enough has been said to show that there need be no difficulty, in providing a good and sufficient water supply throughout England and Wales, if only an efficient scheme were arranged for utilising the different sources of supply.

It has been suggested that the distillation of water in some parts of the country might be useful and economical. The author has had some experience on this point, having lived for some years in a district in South America where all the water supply was obtained by the distillation of sea water; and he does not recommend this system to be adopted where it can possibly be avoided.

It is proposed to divide England and Wales into the 12 districts shown on the maps accompanying this paper.

The river basins of England and Wales are generally classed under four divisions, viz.:—1. The North-West Division, comprising those rivers draining into the Irish Sea and St. George's Channel. 2. The South-West, draining into the Bristol Channel. 3. The Southern Division, draining into the English Channel; and 4. The Eastern, draining into the German Ocean. The lines of water-shed separating these divisions have been, in most cases, retained as boundaries between the proposed districts.

District No. 1, or the North-West District.

This will be a large and a very important district. It includes the whole of the North-West of England, and is, in fact, almost identical with the North-West Drainage Division mentioned above; the boundary of the district agreeing with that of the division from the Cheviot hills to a little south of Bala Lake; it then turns northwards, and follows the western edge of the basins of the Dee and the Elwy, includes the Dulas, and reaches the sea at Colwyn. There are great difficulties in the way of diminishing the size of this district. It may now be considered as decided that the waters of the lake region of Cumberland and Westmoreland will be used for the supply of Manchester and other Lancashire towns, and, therefore, the district must extend from the Lakes to Manchester. It must then include the whole of the Mersey basin, otherwise part of this basin would be under one set of Commissioners and part under another, which would be most undesirable. Then, again, there is great probability that

Bala Lake will be utilised for the supply of Chester and Liverpool, so this must be included in this district. The lakes Ulleswater and Haweswater drain northwards into the Eden, thus extending the district nearly to the extreme north of England. As it is considered, in this scheme desirable, to include the whole area and population of England and Wales, in the 12 districts, the northern boundary of No. 1 has been drawn along the dividing line between England and Scotland, and therefore includes a portion of the basin of the Esk; but, in carrying out the scheme, it would probably be found advisable to omit this, and to stop the district at the northern boundary of the Eden basin. The area of this district is 6,613 square miles. It includes the whole, or nearly the whole, of Cumberland, Westmoreland, Lancashire, Cheshire, Flint, and Denbigh, and portions of Yorkshire, Derbyshire, Merioneth, &c. The population, in 1871, was 3,963,302, and the estimated population now is 4,446,157. It may be as well to mention here that the "estimated population now" has been in all cases obtained by taking the population in 1871, and adding to it the increase since 1861, thus assuming that the increase in the last eight years has been equal to that in the preceding ten. This method, perhaps, gives rather less than the actual increase, but is accurate enough as an approximation.

The principal river basins in the district are the Eden, draining Ulleswater and Haweswater; the Derwent, draining Derwentwater and Thirlmere; the Leven, draining Windermere; the Kent, the Lune, the Ribble, the Mersey, the Dee, and the Elwy. The strata in this district belong to the primary and to the lowest part of the secondary formations, the most recent being the trias. The Lake region of Cumberland and Westmorland consists of the Cambrian or Silurian formations, which again occur round Bala Lake. The mountain limestone and millstone grit of the carboniferous series border the Silurian of Cumberland on the north and east, and form the ridge of the Pennine chain of hills which extend northwards from the High Peak of Derbyshire. They again appear to the south of the estuary of the Dee. The coal measures occur at Workington and Whitehaven, and in the district north of Manchester and Liverpool, and again are slightly developed south of the Dee estuary. The permian strata are found near Whitehaven, and along a narrow strip of country from Allonby on the coast to Penrith and Brough; they also fringe the west and south sides of the coal-fields of Lancashire, and the east of those of Flintshire. The trias, or new red sandstone, is largely developed; it forms the greater part of the basins of the Eden, the Mersey, and the Dee, and also occurs on the south-west coast of Cumberland, the west of Lancashire, and in the small basin of the Clwydd in the north-east of Wales. In the west and north of the district, however, this formation is extensively covered by alluvium.

The rainfall of the Lake district is very large, as much as 225 inches having been registered in one year at the Stye. Mr. Symons has given the true mean of the Lake district as 77 inches, that of three consecutive dry years as 61·6, and of the driest year as 53 inches. On Mr. Symons' map, in the Sixth Report of the Rivers Pollution Commissioners, a rainfall of over 75 inches per annum is given for the Lake district, and for the region from which Bala Lake is fed. The area, coloured as having a fall of between 50 and 75 inches, borders the Lake region, includes the head waters of the Eden, the Lune, and the Ribble, and extends along the eastern edge of the district as far south as Settle. There is a similar area in Wales, including Bala Lake, and reaching to Llanrwst. The next zone, 40 to 50 inches, extends from Silloth and Wigton to the north-east corner of Westmoreland; in Lancashire it includes Lancaster, Blackburn, Bolton, Rochdale, and Burnley. It also borders the last preceeding zone in Wales. Almost the whole of the remainder of the district has between 30 and 40 inches of rain, a portion of Flintshire and the West of Cheshire having less than 30.

The percolation in the permian and new red sandstone areas is large. The metamorphic rocks of the Cumberland and Westmoreland mountains rise to a considerable elevation near the coast, and the district is, on the whole, a very mountainous one, and most of the rivers rise on very high ground. In the northern and south-western parts of the district, where the older strata occur, the rain falling would be carried at once to the sea, were it not for the presence of the lakes, which act as regulators. Those rivers, which are fed from the trias, are much more regular in their flow.

The rivers are for the most part largely polluted either by sewage or by trade refuse, the only exceptions being some small ones near the coast.

Although the population of this district is large, the available water supply is proportionally great, consisting both of upland surface water and of underground water from the trias. The upland surface waters from the upper tributaries of the Mersey and the Ribble, on the millstone grit and mountain limestone, and from other rivers, have already been utilised, and more than 50 million gallons per day are now drawn from these sources, but there is still a vast reserve, in the Lake region, of excellent water, eminently suitable for manufacturing towns on account of its softness. The loss of water by evaporation throughout England and Wales varies from 9 to 20 inches per annum, and in mountain districts is generally taken at 14 inches. The compensation water given to the rivers, when their head waters are impounded, is usually one-third or one-fourth of the amount that can be collected. The area of the lake district is given by Professor Ansted as "nearly 800 square miles." Taking the rainfall of the driest year at 53 inches, deducting 14 inches for evaporation, and taking away one-third for compensation, there is left 26 inches, which would give rather more than one million gallons per square mile per day, or a total, taking the area at 700 square miles, of 700 millions gallons per day; enough to supply 28 millions people, whereas the population of No. 1 District is under 5 millions. The net produce of three or four dry years at the present gathering ground for Manchester, averages 33 inches. Messrs. Hemans and Hassard proposed to supply London by collecting the water from 177 square miles of the Lake district, including only the drainage areas of Ulleswater, Haweswater, and Thirlmere: they estimated the rainfall at 64, the loss at 14, and the compensation at 9 inches, leaving 41 inches, which would produce 287 million gallons per day. They also mention a reserve area of 53 square miles to the east of Ambleside.

The area proposed to be utilised for the Thirlmere scheme is about 17 square miles. Mr. Bateman calculates the mean rainfall at 80 inches, and the loss at 8, leaving 72 inches, which gives about 50 million gallons per day.

Bala Lake has a drainage area of 56 square miles, and it is estimated by Mr. Hassard that 70 million gallons per day could be obtained from it.

The underground water of the trias has already been extensively drawn upon, especially at Liverpool, where, however, it has not proved adequate to meet the demand upon it; owing, no doubt, to the proximity of the sea, and to the presence of faults in the strata.

Some controlling authority is greatly needed in this district, to regulate the supply to the different towns. The gathering grounds of Lancashire might be developed to their fullest capacity, any deficiency in the supply to the manufacturing districts being then made up from the more distant sources. The 70 million gallons per day which could be obtained from the Bala Lake drainage area would amply suffice for the South-Western part of the district, including Liverpool, and the Rivington district could then be given up to the towns in its neighbourhood, as recommended by Mr. Bateman in his evidence before the Commission on Water Supply. The south-eastern part of the district, situated as it is on the new red sandstone, might be supplied from that formation.

District No. 2, or the Welsh District.

This includes the remaining portion of the North-West River System, and that part of the South-West Division which is west of the Wye basin. The extreme south-west corner of the Wye basin, between Chepstow and Newport, as shown on the Catchment Basins Map of the Ordnance Survey Department, has been added to this district, as it does not drain into the Wye. The Wye has not been included in this district, because it is considered that the large body of water which could be obtained from its drainage area could be more usefully employed, and is more required in the Midland counties of England than in the South of Wales. The area of the district is 5,359 square miles, and it contains the whole of Anglesey, Carnarvon, Pembroke, Carmarthen, and Glamorgan, and the greater part of Merioneth, Cardigan, Brecknock, and Monmouthshire. The population, in 1871, was 1,089,926, and the estimated population now is 1,205,021. The principal river basins are the Conway, Glaslyn, Mawddach, Dovey, Teifi, Towy, Tawe, Neath, Taff, Rumney, and Usk. With the exception of a small area in the extreme south of Glamorgan, the strata in this district are entirely of the Palæozoic age, and principally belong to the Cambrian and Silurian, intermixed with trappean rocks. The Devonian or its equivalent occupies the greater part of the portions of Brecknockshire and Monmouthshire included in this district, and the carboniferous, principally consisting of the coal measures, covers a large area in Glamorganshire and Monmouthshire. These two formations also occur in the south of Pembrokeshire. On Mr. Symons' map it is shown that over 75 inches of rain falls on a strip of country extending from Snowdon to Cader Idris, and also on a small area on the borders of the district at Plynlimmon. From 50 to 75 inches falls on the greater part of the district. From 40 to 50 inches falls on the whole of Anglesea, except the centre; on the north coast and western promontory of Carnarvonshire; on the west of Merioneth and Cardigan, on the whole of Pembroke, the south of Carmarthen, the north and east of Glamorgan, and on the east of the preceding zone from Brecon to Cardiff. Less than 40 inches falls on the South coast, from Kidwelly to Llandaff, and in the basin of the Usk below Brecon, while a very small area east of Newport has a less fall than 30 inches.

The greater part of this district is more than 500 feet above sea, and it is separated from districts 1 and 3 by high mountains. In this district, as in No. 1, the rainfall is large and is carried rapidly off the land, but there are numerous small lakes which serve as regulators. A map issued by the Rivers Pollution Commissioners, in their sixth Report, shows that the rivers of this district are unusually free from pollution, the exceptions being those in the centre and those in the south-east. The southern part of the district is important, owing to its coal and iron industries.

The system most applicable to this Welsh district will probably prove to be that of storing the mountain waters. The streams on the west coast of Wales are described as being exceptionally pure, soft, and pleasant, and as the rainfall is considerably above the average, no difficulty will be found in providing an ample water supply throughout the district.

District No. 3, or the Severn District.

This is the largest of the 12 districts. It consists of the basins of the Severn, the Wye, the Bristol Avon, and the Yeo. The boundary on the east is the same as that between the south-west and the eastern river systems. On the south-west the Mendip Hills form the natural boundary of the Severn system. The area is 7,053 square miles. It includes the whole of Radnor and Hereford; nearly the whole of Montgomery, Shropshire, Worcester, Warwick, and Gloucester, and parts of Brecknock, Monmouth, Somerset, and Wiltshire, &c.

The population in 1871 was 1,763,363, and the estimated population now 1,856,754. On the west side of the district, the strata are of the primary age, Silurian in the Welsh counties, and Devonian in Monmouthshire, Herefordshire, and the south of Shropshire. The carboniferous rocks occur in isolated patches near Shrewsbury, in the Valley of the Severn, north and south of Bridgenorth, in the Forest of Dean, around Bristol, and in the Mendip Hills. The permian is slightly developed east of the patches of carboniferous strata in Shropshire, and also round Coventry. The trias occupies the remaining portion of the district to the north-east; the Warwickshire Avon and the lower part of the Severn form approximately its eastern boundary. The lias appears east of this line, and extends north of the Avon at Pershore. The lower and middle oolites occur in the south-west corner of the district, in the upper part of the basin of the Bristol Avon and the upper oolite and greensand are at the extreme south-west, near Devizes. The rainfall is less than in the preceding districts. At the sources of the Severn it is over 75 inches. Then follows a narrow band on the western edge of the upper basins of the Severn and Wye, where it is between 50 and 75 inches. Then another narrow strip, extending to Llanfair, Newtown, and Brecon, where it is between 40 and 50. The next zone, that between 30 and 40 inches, is wider than the former ones, and extends a little east of the Welsh border, and there is a detached area of this zone round Cheltenham, Stroud, and Bristol. The rest of the district has between 25 and 30 inches of rain per annum. The western border of the district is very mountainous, and in the East and South are the Malvern, the Cotteswold, and the Mendip Hills. The centre and north are of lower but still of considerable elevation. In the upper basin the water of the Severn is soft, and free from mineral solids, but the eastern tributaries convey harder water from the triassic districts, and a large part of the main stream itself runs over the trias. This district would not be a difficult one to deal with, as the head waters of the Severn and the Wye would, if necessary, furnish an ample supply for the whole of it.

Mr. Bateman, in his scheme for supplying London from the sources of the Severn, proposed to collect the water from 204 square miles, and also pointed out a reserve area of 109 square miles in the basin of the Severn, and 60 in that of the Wye. He took 36 inches as the rainfall that he should be able to collect; which, after deducting one-fourth for compensation, would give about 220 million gallons per day; but he estimated the available quantity from the whole area at 300 million gallons. This would be enough for 12 million people.

Mr. Hamilton Fulton, again, estimated that there could be obtained from 440 square miles, in the catchment area of the Wye, after giving one-fourth for compensation, 393 million gallons per day. The proposed aqueducts in both these schemes keep in this district as far as the south-east corner of Warwickshire. In addition to the large body of water thus shown to be available in the west, a considerable supply could be obtained from the triassic strata in the north and east, and from the oolitic in the south-east.

District No. 4, or the South-West District.

This is composed of the remaining part of the south-west river system, and of part of the southern system. The division between these two systems extends in a very irregular manner, through Devon and Cornwall, and would make a very inconvenient boundary between different districts. It is proposed that this division should be followed from the south point of the basin of the Bristol Avon to near Crewkerne, and that the boundary should then be drawn down to the sea, between Lyme Regis and Bridport, so as to include the basins of the Axe and the Char. The Mendip Hills form the north-east boundary. The area of the district is 5,103 square miles. It contains the whole of Devon and Cornwall, and the greater part of Somersetshire. The population, in 1871, was 1,253,928, and the estimated population now is 1,264,767. The principal river basins are the Parret, the Taw, the Torridge, the Tamar, the Dart, the Teign, the Ex, and the Axe. Palæozoic rocks form the greater part of the district. The Devonian system extends over most of Cornwall, and is largely developed in the north and south of Devonshire. The lower carboniferous strata occupy the centre and west of Devonshire. The trias is represented by a strip stretching from north to south across Somerset and Devon, and including Bridgwater, Taunton, Exeter, and Sidmouth. The lias is found in the centre and north of Somersetshire, and extends to the Channel at Lyme Regis. The lower oolite forms the high ground on the eastern boundary of the district, while an outlier of the cretaceous system occurs in the south-east corner of Devonshire, in the basins of the Axe and Otter. Granite and metamorphic rocks form elevated areas at Dartmoor and in several parts of Cornwall. The rainfall exceeds 75 inches at Dartmoor. It is between 50 and 75 inches on the outskirts of the moor, and on the granite hills between Launceston and Bodmin. Almost the whole of the remaining part of Cornwall and the west of Devonshire has from 40 to 50 inches, and this extends eastwards to Barnstaple and Plymouth, and the east side of Dartmoor. The neighbourhood of Falmouth has rather less than 40 inches, and the fall is between 40 and 50 inches in the east of Devonshire, and the west and south of Somerset, and also in the north-east of Somerset at Wells and Glastonbury. The remaining portion of Somerset has less than 30 inches. The elevation of the greater part of this district is considerable, rising to about 1,800 feet in Dartmoor. Most of the river basins are shown as unpolluted on the map of the Rivers Pollution Commissioners. In this, as in the preceding districts, there is a large quantity of upland water available, owing to the heavy rainfall, and to the geological formations represented being principally of the palæozoic age, and therefore of an impermeable character. There are numerous streams of pure water rising in Dartmoor, and the elevated regions of Cornwall and the north of Devonshire would give large supplies. The more permeable rocks at the east of the district furnish underground waters.

District No. 5, or the Southern District.

This contains another portion of the southern drainage division, namely, that extending from the last district to the eastern side of the basin of the Titchfield, and including the Isle of Wight. The North Downs form the north-east boundary. The area is 2,798 square miles. The district includes the greater part of Dorsetshire and Hampshire, and about one-half of Wiltshire. The population in 1871 was 593,175, and the estimated population now is 637,638. The chief river basins are the Frome, Stour, Avon, Test or Anton, Itchin, and Titchfield. The oldest formation represented in this district is the lower oolite which forms the high ground at the south-west boundary of the district, and extends along the coast to Weymouth. This is succeeded by the middle and upper oolites in the south-west of Wiltshire and north of Dorset, and at Weymouth and Portland. The greensand forms a narrow band towards the western side of the district, and in the Isle of Wight; while the chalk is largely developed, extending from Purbeck to Dorchester, and thence through the centre of Dorsetshire, forming the whole of the district north of Salisbury and Winchester. It also forms the centre ridge of the Isle of Wight, and underlies the tertiary strata which cover the east of Dorsetshire, the south of Hampshire, and the north of the Isle of Wight. The rainfall of this district is only moderate in quantity. The highest zone is that between 30 and 40 inches; this covers the southern part of the district, and includes Shaftesbury, Salisbury, and Winchester. The rest of the district has between 25 and 30 inches per annum. This district is of less elevation than the preceding ones, but it is bounded on the west by the oolitic hills, separating it from No. 4, and on the north by the chalk hills forming Salisbury Plain and the commencement of the North Downs.

The map before referred to shows that in the whole of Dorsetshire, in nearly the whole of Wiltshire, in the south of Hampshire, and in the Isle of Wight the river basins are unpolluted. As there is a large area occupied by permeable strata, more especially by the chalk, large quantities of underground water could be obtained in this district. Water is also now collected from the surface of the lower tertiaries; this is described by the Rivers Pollution Commissioners as probably not unwholesome. In some parts of the tertiary area the supply is at present unsatisfactory; but there would be no difficulty in providing good water for all the wants of the district from within the district itself.

District No. 6, or the South-east District.

This is made up of the remaining portion of the Southern river system, and the basins of the Medway and the Stour. The reason for including these two basins is that their interests, as regards water supply, are in no way bound up with those of the Thames basin, and the latter will form by itself a district so large and populous that it is advisable to limit it wherever possible. The division between districts No. 5 and 6 is an arbitrary one, and there would be no difficulty in uniting them if it were thought desirable; but considering that when so united they would form a very long district—longer, in fact, than any of the others, and that there is no reason, connected with their geological formations, or with the sources of water supply available in each district, why they should not be separated, it has seemed to the author preferable to form them into two distinct districts. They will not be by any means unimportant. There are numerous health resorts scattered along the coast, at which it is most essential that there should be a good supply of pure water. The area of this district is 3,057 square miles, comprising the whole of Sussex, the greater part of Kent, and part of Hampshire and Surrey. The population in 1871 was 1,094,186; the estimated population now is 1,225,214. The river basins are the Portsmouth, Arun, Adur, Ouse, Rother, Medway, Stour, &c.

There is no geological formation here older than the wealden, which occupies the centre of the district in the Weald of Kent and Sussex; it extends to the northern boundary of the district, but on the west, the south, and the north-east it is surrounded by a narrow strip of the greensand strata, while the chalk stretches from Brighton and Beachy Head towards Winchester, forming the South Downs, and enters the district again at Rochester, extending to Dover and Deal, and forming the eastern spur of the North Downs. The tertiary clay forms a narrow strip along the coast from Brighton to Fareham, and again north of Rochester and Canterbury. The rainfall is about the same as in No. 5. It is between 30 and 40 inches over the central part, and between 25 and 30 over a narrow area along the south coast, including Havant, Chichester, Lewes, and Battle, and over a wider one on the north and east, reaching from Chatham, Canterbury, and Sandwich, nearly to Tunbridge Wells and Ashford. The extreme north of Kent, including the Isles of Sheppey and Thanet, has less than 25 inches.

The centre of the district is of moderate elevation; it rises to about 640 feet. The rivers are for the most part short and unimportant. Their basins, with the exceptions of the Medway and a small area round Canterbury, are unpolluted. The country covered by the wealden strata is not very abundantly supplied with water; but, as the population is not great, there will probably prove to be a sufficient supply in the springs and wells. Although the water from this formation is inferior, both in quality and quantity, to that from that from the new red sandstone, the oolite, and the chalk, it is yet good and wholesome, and sometimes soft. Tunbridge Wells is supplied from a spring in the wealden, and Hastings from an artesian well. In that part of the district where the chalk and greensands occur, an ample supply of good water could be obtained, and in many places has already been. The chalk springs near Havant are so abundant that it was even proposed by Mr. Ewens, before the Royal Commission on Water Supply, to utilise them for the supply of London. They can, however, be more profitably used in the populous district in their neighbourhood.

District No. 7, or the Thames District.

This is conterminous with the catchment area of the River Thames, excluding the Medway. Although of less area than some of the other districts, it contains the greatest number of inhabitants. If, as is proposed, the future supply of London be obtained within the catchment area of the Thames, it seems impossible to separate the interests of the metropolitan district from those of the other towns and villages in that area and the whole basin should, therefore, be placed under one authority as regards its water supply—which authority should also have complete control over the River Thames itself and its tributaries.

The area of the district is 5,172 square miles. It includes the whole, or nearly the whole, of Oxfordshire, Berkshire, Hertfordshire, Middlesex, and Surrey, with large portions of Buckinghamshire, Gloucestershire, Wiltshire, Hampshire, Kent, and Essex.

Its population in 1871 was 5,040,096, and its estimated population now is 5,804,351. The lias is the most ancient of the geological formations in this district; it is found only at the extreme northwest. The lower oolitic strata of the Cotteswolds are of great importance, for on these rise many of the most important of the earlier feeders of the Thames. The middle and upper oolites follow in narrow bands. The wealden in the south part of the district gives rise to the Mole. The greensand stretches from between Aylesbury and Tring, southwards, through Wantage, towards Devizes, and also occurs in Surrey, south of the North Downs. The chalk is of greater extent, and reaches from the greensand on the west to Bishops Stortford, Hertford, Watford, Reading, and Hungerford; it then forms the crest of the North Downs, and the lower part of the valley of the Darent.

The remainder of the district consists of the tertiaries overlying the chalk. Of these the London clay covers the largest area, but there is a considerable extent of country, about 200 square miles, round Bagshot covered by the permeable Bagshot sands. The rainfall is nowhere very great. The average of the upper basin is about 30 inches, and that of the whole basin is 26 or 28 inches per annum. The highest zone on Mr. Symons' map is that between 30 and 40 inches, covering a small region at the head of the Thames, Churn, and Coln, and another at the head of the Wey and Mole. The next zone, 25 to 30, extends eastwards as far as Oxford, and nearly to Reading, and takes in all south of a line drawn from just below Reading to Croydon, and to below Gravesend. There is also an isolated portion of this zone round Tring, St. Albans, and Luton. The rest of the district has a fall of less than 25 inches. There are several ranges of hills of considerable elevation in the west and south; namely, the Cotteswolds, the Chilterns, and the North Downs. The water-shed between the Thames and the Severn is at the highest over 800 feet, but mostly below 400 feet. That between the Thames and Ouse is generally not more than 300 feet. The flow of the rivers is large in comparison with their drainage areas. They are all shown as polluted on the map of the Rivers Pollution Commissioners, but they do not of course become polluted for some little distance below their sources. The mean evaporation throughout the basin is usually assumed at 15 inches, but Mr. Greaves considers that near London it is 18 inches, or 72 per cent. of a rainfall of 25 inches. There is a large percolation over most of the district, and Mr. Bravender estimates the mean amount of rainfall available in the upper part of the basin at between 9 and 11 inches. The amount of percolation through the chalk, estimated by different authorities, varies from 4 to 18 inches per annum.

The evidence taken by the Commissioners on Water Supply, and on Rivers Pollution, proves conclusively that there is an ample supply of water in this district for all its inhabitants. On the west, abundant streams of excellent water are poured forth from the oolitic rocks, while in the centre and the east, the chalk furnishes a large supply, not only at the outcrop, but even where it passes under the tertiaries.

The Royal Commissioners on River Pollution say, in their 6th report:—"We have found no catchment basin so rich in springs of the finest drinking water as that of the Thames. The chalk, oolite, and greensand make up a very large proportion of the collecting ground of the Thames basin, and even where they dip below the London clay, or the other impermeable formations, are easily accessible to the boring rod. We are of opinion that the whole of the metropolis and its suburbs should be supplied exclusively with the spring and deep well water of the Thames basin." They further state that, within 40 miles of St. Paul's, a sufficient volume of deep well and spring water can be obtained for the present daily wants of the metropolis, and they estimate that, taking only 6 inches of the rain-fall, 512 million gallons per day could be obtained within 50 miles.

Mr. Bailey Denton, in his evidence before the Commission on Water Supply, estimated that 100 million gallons per day could be obtained from the upper sources of the Thames, 60 million gallons from the Lea, and 40 million gallons from the Wey and Mole, making a total of 200 million gallons exclusive of the Colne and the Wandle.

Mr. Hawkesley considered that half of the lowest volume of the Thames, which he calculated at 360 million gallons per day, might be taken without any storing process. Mr. Simpson thought the Thames capable of supplying 200 million gallons per day, and the Lea 60 million. Mr. Beardmore said that with storage reservoirs 300 million gallons could be obtained from the Thames and Lea. Mr. Leach, engineer to the Thames Conservancy, said there was a district above Oxford well calculated for the formation of reservoirs, and thought that, with storage reservoirs, 200 million gallons per day might be taken. The Commissioners summed up the evidence by estimating that 220 million gallons could be obtained from the basin of the main stream, 50 million from that of the Lea, and 30 million from the chalk, making a total of 300 million gallons per day. The present supply to London is about 120 million gallons a day. If, however, we take the population of the whole water-shed at six millions, this multiplied by 25 gallons, will give 150 million gallons per day; just half the quantity estimated to be available in the water-shed. The estimate of 30 million gallons obtainable from the chalk is an exceedingly moderate one, and the quantity now drawn daily from this formation in the whole water-shed is probably nearly, if not quite, as much as 30 million gallons. Large quantities are obtained from wells in London itself. The Kent Water-works Company pump from their wells on the outskirts of the Metropolis enough, it is said, to supply the whole of London with sufficient water for drinking and cooking. At Grays, in Essex, as much as 7 million gallons per day has been raised, and the district in the neighbourhood is now supplied from this source.

From the chalk wells of the Tring and the Caterham Water-works Companies, and of the New River Company, several million gallons a-day are obtained. It would extend this paper to too great a length to go fully into the evidence that has been given, from time to time, as to the area of the different formations in the Thames basin; as to the extent to which they may be depended on to furnish water; and as to the actual flow of the Thames and its tributaries. The reports of the Royal Commissioners go very fully into those questions, and they have been frequently discussed since those reports were issued. The author will only, therefore, sum up by expressing his conviction that it will be quite unnecessary to go beyond the basin of the Thames for the supply of the population of that basin, within any time that we need at present look forward to. He does not feel called upon to say anything as to the mode in which the present supply should be improved, but will repeat what has been stated in a former part of this paper, that no scheme can be considered satisfactory which does not take into account the large amount of capital already expended on water-works.

District No. 8, or the Eastern Counties District.

Several different ways of dividing the country between the Thames and the Humber might be suggested, each having its advantages. The basins of the Great Ouse, Nene, Welland, Witham, and Trent are connected by artificial cuts or canals, so that it is impossible to create districts which shall be entirely independent of each other. Much might be said in favour of uniting together the four large rivers that drain into the Wash; namely, the Ouse, the Nene, the Welland, and the Witham; but this would leave two small and inconvenient districts, one on the coast of Lincoln, and the other on the coasts of Norfolk, Suffolk, and Essex; or if these were included in the same district as the four large rivers, this district would be of great size. The author, after much consideration, has determined to separate the Ouse from the other Fen rivers, and to make this No. 8 district consist of the basin of the Great Ouse, and all the country to the east of it. That portion of the basin of the Ouse, however, which is in the Middle Level, has been placed in the next district, so that the whole of the Middle Level might be in the same district as the Nene, from which it usually draws its water supply.

The area of District No. 8 is 6,394 square miles. Its population in 1871 was 1,437,804, and its estimated population now is 1,483,329. It contains the whole of Suffolk, nearly the whole of Bedfordshire, Cambridgeshire, and Norfolk; and parts of Northampton, Buckinghamshire, Huntingdon, Essex, &c. The principal river basins are the Great Ouse, Yare, Waveney, Orwell, Stour, Colne, and Blackwater. The lias occurs only in the extreme west, in Northamptonshire. The lower oolite follows and extends to Buckingham and Bedford. The middle and upper oolites succeed, widening out in Huntingdonshire, where there is a considerable area covered by the Oxford clay. The greensand stretches from the south-west of Bedfordshire to Ely, its eastern boundary passing near Dunstable and Cambridge. It also forms the eastern border of the Valley of the Ouse, from a little below Ely to Hunstanton. The chalk forms a zone of considerable breadth, including the east of Cambridgeshire, the west of Suffolk, and the greater part of Norfolk. The eastern portion of this area is, however, largely covered by newer deposits. On the eastern and south-eastern borders of this district are the tertiaries, belonging for the most part to the upper division, overlying the chalk.

The rainfall of the whole district, with the exception, perhaps, of Leighton Buzzard, is less than 25 inches per annum.

The northern and eastern parts of the district are low, but in Northamptonshire, and in the south of Bedfordshire, there are hills of considerable elevation, and there are the Gog Magog hills and the East Anglian hills in Cambridgeshire and Norfolk respectively. The Great Ouse brings down large volumes of water in winter and spring, generally causing extensive floods, but in summer its flow is comparatively small. Its sources are in the lower oolites, at an elevation of nearly 300 feet. The river basins are polluted, except in Essex, in the east of Suffolk, and in the north of Norfolk. The centre and east of this district have the greensand and the chalk as their sources of water supply, while the extreme west has the lower oolite. The region most difficult to deal with will be that covered by the Oxford clay. This stratum is of great thickness, and contains very little water. Huntingdon, which is situated on this formation, has obtained a good supply from a gravel hill, to the west of the town.

District No. 9, or the Lincolnshire District.

This is composed of the basins of the Nene, the Welland, the Witham, and the Ancholme, together with the small basins on the east coast of Lincolnshire, and with that part of the Middle Level which is in the basin of the Ouse. Its area is 3,952 square miles, and it includes nearly the whole of Lincolnshire, Rutlandshire, and Northamptonshire, with part of Huntingdonshire, Cambridgeshire, Norfolk, &c. Its population, in 1871, was 740,836, and its estimated population now is 781,709. The lias forms the western boundary of the district; reaching to Northampton, Oakham, and Lincoln. The lower oolite is found along the valley of the Nene, from Northampton to Peterborough, and forms a band of considerable width through the centre of Lincolnshire, from the north to the south. The Oxford clay of the middle oolite is not very extensively developed on the surface, but passes under and forms the basement of the greater part of the Fens, except in the south, where it is replaced by the Kimmeridge clay of the upper oolite. The upper oolite, greensand, and chalk succeed one another in the north-east of Lincolnshire, from the mouth of the Ancholme to Wainfleet. The chalk is covered near the coast by more recent deposits. The rainfall of this district ranges from 25 inches to 20 inches, or even less. Twenty-one or 22 inches is usually given as the rainfall of the Fens.

The south-eastern part of the district is flat, but in the west there are hills of moderate elevation, and in the north-east are the Lincolnshire Wolds. The Nene and Witham rise at an elevation of about 300 feet. The Fen rivers bring down floods in the wet seasons, but dwindle to comparative insignificance in the dry seasons. A great amount of labour and money has been expended on them during the last three centuries, but with only partially satisfactory results.

The eastern part of the district is not coloured as polluted on the map of the Rivers Pollution Commissioners, but the lower parts of the basins of the Witham and the Welland can scarcely be considered as being free from pollution.

The south-eastern portion of the district will prove a most difficult country to provide for; but that the difficulty is not insuperable is proved by the fact that the larger towns, such as Boston, Spalding, Peterborough, and Wisbeach, have succeeded in obtaining good supplies of water at a moderate expense.

In the north-eastern portion, the cretaceous strata may be relied on to furnish a supply. Mr. Shelford mentioned at the Congress last year that a large body of water finds its way from the chalk wolds of Lincolnshire to the German ocean. The county of Northampton is remarkable for the number of springs proceeding from the lower oolites, and in the south of Lincolnshire, in the district round Bourn, large volumes of water are given out by these strata in springs and wells. The Braceborough Spa, which is still not utilised, is said to give a million gallons per day.

The present supply to the villages in the Fenland is most unsatisfactory, many of them being supplied from polluted shallow wells in the surface gravel, and others from the rivers and drains. Much of the lower part of the Nene basin and of the Middle Level has no source of supply except the River Nene, below where the sewage of Peterborough is, or was until lately, poured into it. Unfortunately the lower oolites which give such a liberal supply in the centre of the district thin out as they pass under the more recent strata in the east and south-east. Thus water cannot be obtained in the Fen-land by boring, but must be brought from a distance.

District No. 10, or the Midland District.

This is formed by the basins of the Trent, the Derwent, and the Don. It is bounded on the West and South by the line of water-shed separating the River System of the East of England from the North-West and South-West Systems. There will be no great difficulty in separating the Don from the more northerly part of the Humber basin, and placing it under the same jurisdiction as the Trent. This jurisdiction will extend to the out-falls of these rivers into the Ouse.

The area of this district is 4,732 square miles. It takes in nearly the whole of Derbyshire, Staffordshire, Leicestershire, and Nottinghamshire, and part of Yorkshire, Lincolnshire, Warwick, &c. Its population in 1871 was 2,746,190, and its estimated population now is 3,133,837. The carboniferous formation forms the north-west of the district, and occurs in detached portions in the South. In South Staffordshire and South Yorkshire are coal fields, while the mill-stone grit and mountain limestone cover a wide band of country in the north-west, in which are the sources of the Dove, the Derwent, and the Don. The permian adjoins the patches of carboniferous in the south, and forms a border on the east to the South Yorkshire coal-field, extending east to Nottingham and Doncaster. The magnesian limestone in the valley of the Don has a considerable thickness. The trias occupies nearly the whole of the remainder of this district, leaving a narrow strip on the eastern border which is covered by the lias.

The maximum zone of rain is that between 30 inches and 40 inches. This occupies the north-west corner, and extends to Sheffield, and includes the west of Derbyshire, and the north and centre of Staffordshire. The next one, 25 to 30 inches, forms a narrow strip in the south-east of Yorkshire, covers the south of the district, and extends east as far as Leicester, Mansfield, and Rotherham. The rest of the district has less than 25 inches. In the Peak district of Derbyshire, and at the head waters of the Don, the hills are of considerable elevation, but in the north-east of the basins of the Don and Trent are large tracts of low-lying land covered with alluvium. The Trent and Don are subject to floods, and generally have a considerable flow. Their waters are polluted.

There is abundance of water in this district. The head waters of the Don are already largely drawn upon for Sheffield and other towns, but in the north of Derbyshire are gathering grounds not hitherto utilised. Mr. Easton, in his evidence last year on the Thirlmere scheme, said that there are 20,000 acres available at the head waters of the Derwent and its tributaries, 800 feet above the sea, besides smaller areas, sufficient to provide the compensation water, and he estimated the total available quantity from the 20,000 acres at 50 million gallons per day.

The Commissioners on Water Supply mention a scheme of Mr. Remington for bringing water from the hills of Derbyshire to London; collecting it at a point above Mill Dale on the Dove. The area proposed to be utilised was 262 square miles. The rainfall was taken at 48 inches, and Mr. Remington expected to be able to collect one-sixth of this, giving 83 million gallons per day.

In addition to these upland waters, there exists a large reservoir of water in the trias. The area of the trias in the basin of the Trent is given by Professor Ansted as 2,500 square miles, but over a large part of this area the trias is covered by drift or alluvial gravel. The South Staffordshire Waterworks and the Staffordshire Potteries Waterworks draw large supplies from these strata, and many of the towns situated on this formation are supplied with water from it—such are Birmingham, Leicester, Nottingham, &c. In Leicestershire, where the bunter and permian beds are penetrated, the supply is enormous, and entirely unaffected by dry seasons, and it is pure and perfectly soft. (See First Report of the Committee on Underground Waters, appointed by the British Association).

District No. 11, or the Yorkshire District.

This is bounded on the north by the basin of the Tees, and on the west by the Pennine Chain. Its area is 4,682 square miles, and it includes the greater part of Yorkshire. Its population in 1871 was 1,871,933, and its estimated population now is 2,167,202. It contains the basin of the Ouse, with those tributaries above the Don. It also contains the basins of the Hull, &c., on the north of the Humber, and those of the Esk, and some other small rivers in the north-east of Yorkshire, which it is considered should belong to this district rather than to the succeeding one. The lower carboniferous forms the western part of the district, and a small area of coal measures occurs in the south. The permian forms a strip across the centre, thinning out towards the north. The trias occupies a considerable area along the valley of the Ouse, from Richmond to the outfall into the Humber, and also forms the valleys of the lower part of the Derwent and of the Aire. A band of lias borders on the north and west, the oolite hills of the north-east of Yorkshire. The chalk wolds in the south-east of the district are fringed on the west by the greensand and the Kimmeridge clay. East of the River Hull the chalk is covered by recent deposits. A large area of the trias is thickly covered with alluvium and boulder clay. The rainfall in the extreme west is between 40 and 50 inches. The zone of 30 to 40 inches includes Huddersfield, Bradford, and Richmond. That of 25 to 30 inches extends to Wakefield, Knaresbourgh, and Northallerton, and there is an isolated area on the hills in the east. The rest of the district has less than 25 inches. The western and north-eastern portions of the district are very elevated, the south-eastern being of less elevation. The eastern part of Yorkshire, including the basin of the Derwent, is unpolluted. The western side of this district is well suited for the collection of upland waters. The Commissioners on Water Supply say that the Yorkshire manufacturing towns can be well supplied from districts near to them. These districts already furnish large quantities of water. At Leeds, Bradford, and Halifax the supply to the suburbs and the towns is nearly 20 million gallons a day.

The oolitic strata in the north-east, and the chalk in the south-east supply the eastern side of the district. Mr. Mortimer, in a paper published in the 55th volume of the Proceedings of the Institution of the Civil Engineers, says, that the area of the out-crop of the chalk of Yorkshire is about 420 square miles, with an average rainfall of 27 inches, and that the extent of sub-aerial water-containing chalk is 780 square miles, whose average depth may be taken at 350 feet. The minimum water line in the country to the east of the out-crop is in no case more than 300 feet deep.

District No. 12, or the North-Eastern District.

This is the last district. It is bounded on the west by the mountainous water-shed separating the east and north-west river systems. The same difficulty occurs in this district as in No. 1.; namely, that the northern boundaries of the river basins are not identical with the boundary between England and Scotland. In calculating the area and population of the district, this latter boundary has been taken as the northern limit. In drawing up a working scheme, it would probably be found convenient, either to include the whole of the basin of the Till, a tributary of the Tweed, which would necessitate the taking into the district of a small part of Roxburghshire, or else to exclude the catchment area of of the Tweed altogether. The area of the district is 3,405 square miles. It includes the whole or nearly the whole of Northumberland and Durham, and small portions of Cumberland and Yorkshire. Its population in 1871 was 1,109,369, and its estimated population now is 1,336,013.

The most important rivers are the Tyne, the Wear, and the Tees. The geological formation is almost entirely carboniferous, and chiefly the carboniferous limestone. There is a coal-field in Durham, and the south of Northumberland. The permian occurs in the east of Durham, and the trias in the extreme south-east, from Hartlepool to Darlington. There are trappean rocks in the Cheviot Hills, and they form the dykes which traverse the district.

The rainfall, according to Mr. Symons' map, does not exceed 50 inches. There is a fall of between 40 and 50 inches in the north-west, from Haltwhistle northwards. The 30 to 40 inches zone extends to about the middle of the district, and the 25 to 30 inches occupies all the remainder except to the east of Durham and Darlington, where it is less than 25 inches. This district is a mountainous one, the Pennine and Cheviot Hills rising to great elevations. The river basins, north of the Tyne, are unpolluted.

The water supply to many parts of this district is at present unsatisfactory, being drawn from rivers polluted by sewage. Some of the towns, however, have sought and obtained purer supplies. The permian in Durham yields unusually large supplies, and it is stated in the third report of the British Association Committee that 5 million gallons per day are pumped from an area of 50 square miles without altering the level of the water. This is used for the supply of Sunderland and the adjacent district. Other towns are supplied by springs from the mountain limestone; and others, again, as, for example, Newcastle—from upland gathering-grounds.

These districts would not be entirely independent of one another. Canals and drains, in many instances, take water from one district and convey it to another. Thus, the Foss Dyke goes from the Witham to the Trent, the Middle Level Drain from the Nene to the Ouse, &c. Some cases occur in which a town situated in one district obtains water from another; as, for example, Wolverhampton, Wisbech, and Dewsbury. These and other points could be easily arranged between the different bodies of Commissioners.

In conclusion, the author hopes that it will be remembered that this scheme is only put forward as a suggestion, not as a final or working scheme. Before any working scheme is drawn up, it will be necessary to have a thorough examination made of all the sources of water supply available in the country. Very little is known with certainty as to the amount of rainfall which can be collected in any district, either as upland water, or as subterranean water. Accurate information is also needed as to the existing water supply to every town and village in the kingdom, and as to the gathering grounds already utilised for the collection of upland surface water. Very few of the rivers have been regularly gauged, so that it is impossible to ascertain what proportion of the total rainfall reaches the rivers. All these points must be gone into before a satisfactory scheme for the water supply of England and Wales can be made.

Schedule of Proposed Districts.

Number.	Area Square Miles.	Estimated Population.
1	6,613	4,446,157
2	5,359	1,205,021
3	7,053	1,856,754
4	5,103	1,264,767
5	2,798	637,638
6	3,057	1,225,214
7	5,172	5,804,351
8	6,394	1,483,329
9	3,952	781,709
10	4,732	3,133,837
11	4,682	2,167,202
12	3,405	1,336,013
Total	58,320	25,341,992

Population in 1871, 22,704,108.

ESSAY BY JOSEPH LUCAS.

Motto—"Gutta cavat lapidem, non vi, sed sæpe cadendo."

AWARDED A SILVER MEDAL.

SYNOPSIS OF PAPER OF SUGGESTIONS.

A. PREFATORY. AREAS AND BOUNDARIES OF DISTRICTS.
    Objections to existing Areas and Boundaries.
B. SUGGESTIONS FOR NEW DISTRICTS.
    i. As to Watershed Areas.
    ii. Illustrations of Grouping ditto.
    iii. Subdivision of ditto.
C. WATERSHED BOARDS.
D. (a.) COMMISSIONERS' DISTRICTS.
    (b.) Sub-Commissioners' Districts.
    (a.) Limits of Northern, Midland, and Southern Commissioners' Districts.
    (b.) Limits of Sub-Commissioners' Districts.
E. RAINFALL.
F. GEOLOGY.
G. POPULATION.
H. CONSTITUTION OF WATERSHED BOARDS.
    i. Respecting the Claims of Boards of Guardians to be Represented.
    ii. As to the Representation of Landowners.
    iii. As to the Representation of Towns.
    iv. Miscellaneous Suggestions, bearing on Constitution of Boards.
J. LOCAL GOVERNMENT BOARD AS A CENTRAL AUTHORITY.
K. COMMISSIONERS OF WATERSHED BOARDS.
L. ENGINEERING STAFF TO WATERSHED BOARDS.
M. PROVISIONS IN RIVERS CONSERVANCY BILL WHICH RELATE TO AREAS AND BOUNDARIES, AND ARE ADAPTED, AS MODIFIED, TO WATERSHED BOARDS. CLAUSES 1 TO 7 (INCLUSIVE), 33, 37, 39, 40, AND 41.
N. RÉSUMÉ.
O. MISCELLANEOUS CONSIDERATIONS, TENDING TO THE ESTABLISHMENT OF WATERSHED BOARDS.
P. AS TO THE ADVISABILITY OF INTERPOSING COMMISSIONERS BETWEEN WATERSHED BOARDS AND THE LOCAL GOVERNMENT BOARD.
Q. PROVINCE OF THE THREE COMMISSIONERS.
R. DUTIES OF WATERSHED BOARDS.
S. POWERS OF DITTO.
T. DUTIES OF SUB-COMMISSIONERS.
U. PRESIDENT OF LOCAL GOVERNMENT BOARD TO RETAIN PRESENT FUNCTIONS AS REGARDS SUGGESTED WATERSHED BOARDS.
V. RESPECTING APPOINTMENT OF COMMISSIONERS.
W. GENERAL VIEW OF ADVANTAGES OF PROPOSED ARRANGEMENT.
X. CONCLUSION.

APPENDIXES.

A. LIST OF AUTHORITIES.
B. TABLE I. SHOWING WATERSHED BASINS, AREAS, RAINFALL, AND GEOLOGY OF COMMISSIONERS' AND SUB-COMMISSIONERS' DISTRICTS, AND OF 36 GROUPS OF WATERSHEDS. TABLE II. SHOWING COUNTIES AND PARTS OF COUNTIES, AND POPULATIONS, IN COMMISSIONERS' AND SUB-COMMISSIONERS' DISTRICTS. TABLE III. SUMMARY OF TABLES I. AND II.
C. MAP OF COMMISSIONERS' AND SUB-COMMISSIONERS' DISTRICTS.

AREAS AND BOUNDARIES OF DISTRICTS.

A.—OBJECTIONS TO EXISTING AREAS AND BOUNDARIES.

"Existing boundaries are altogether independent of sanitary considerations[*]. They frequently cut a row of houses in half, and an urban district terminates in the middle of a street."[†] . . . "Several boundaries of adjoining districts sometimes converge and meet in the centre of the most populated part of the district[‡]." . . "If areas are extensive, they constantly lead to complaints on the part of sections of the community of rural districts, that practically they are not represented on the governing body, that the meetings of the authority are far away at the other end of the districts, and that no interest whatever is taken in their concerns by gentlemen who live at a distance[§]." . . . "On the other hand, if areas be small, it is impossible to provide and properly remunerate officers duly qualified for the important duties they should discharge[||]."

Local administration under [¶] "central superintendence" was the gist of the recommendation of the fertile report of the Sanitary Commissioners of 1869. They say:—

"The smallness of the parochial unit minimises the material for public officers. Imperfect local administration has been the natural result. Local administration must be maintained, but simplified, strengthened, and set in motion.[**]"

In consequence of these recommendations,[††] the areas of unions were made sanitary districts, and Board of Guardians were made sanitary authorities, while the Local Government Board was created and made the central authority. [34 and 35 Vict., c. 70.][‡‡]

In this, the substantial part of their recommendation, that "local administration must be maintained, but simplified, strengthened, and set in motion" appears to have been swamped. While there is still wanting "a real motive power, and an authority to be referred to for guidance and assistance by all the sanitary authorities,[§§] some organisation[||||] corresponding to the Ordnance Survey and the Geological Survey, which should really bring before the local bodies, before they acted, the means by which they might act, and the resources with which they had to deal," the Local Government Board, for want of the very same kind of information, being unable to suggest a remedy applicable to such small areas of collection and distribution of water supply, and of taxation, as those with which they frequently have to deal, have found it impracticable[¶¶] to put into execution the compulsory powers conferred upon it by the Public Health Act (1875.) [38, 39 Vict. c. 55.]

It simply comes to this, where compulsion would be necessary it is because the areas are too small for the authorities to act without pressure, and for the same reason too small to admit of that pressure being effectively applied; and, where areas are large enough, no pressure has been found to be necessary.

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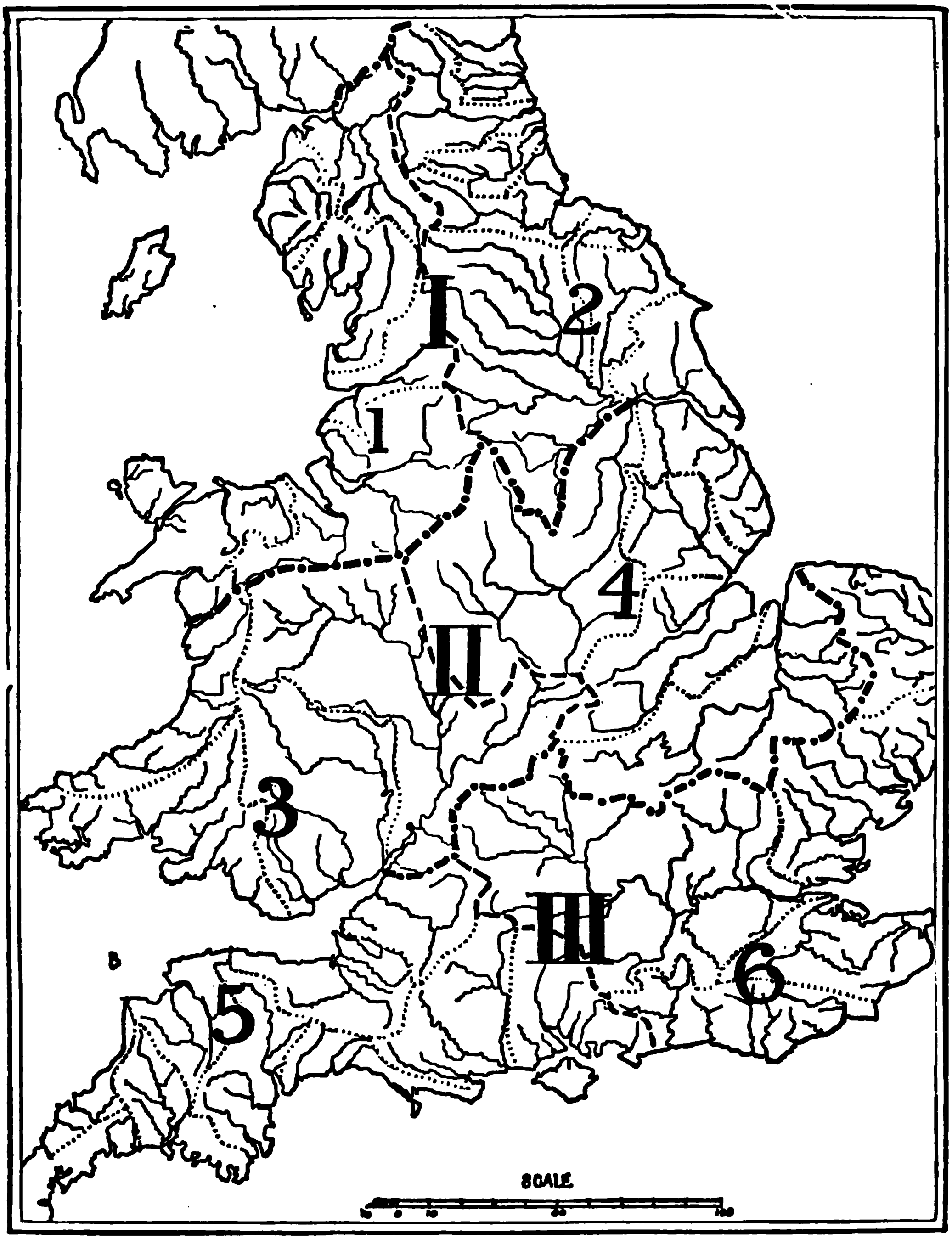
[*] "The Working of the Sanitary Acts in Rural Districts," by W. H. Michael. (Transact. Inst. Surveyors, Vol. VIII., p. 363.)
[†] *Ibid*, p. 365.
[‡] *Ibid*, p. 369.
[§] *Ibid*, p. 369.
[||] *Ibid*, p. 369.
[¶] Royal Sanitary Commission, 1869, Report, p. 16.
[**] *Ibid*, p. 16.
[††] *Ibid*, p. 24.
[‡‡] *Ibid*, p. 31.
[§§] *Ibid*, p. 31.
[||||] Congress on National Water Supply; Disc., G. W. Child, p. 4.
[¶¶] Dr. G. W. Child, p. 7; Dr. Syson, p. 9.



MAP OF DISTRICTS PROPOSED BY JOSEPH LUCAS.

Boundaries of Commissioners' Districts (I, II, III), thus :— ▬ • ▬ • ▬
,, of Sub-Commissioners' Districts' (1, 2, 3, 4, 5, 6), thus : – – – –
,, of Groups of Basins, thus :— ......

ı.—SUGGESTIONS AS TO NEW DISTRICTS.

As to Watershed Areas.—Popular opinion, ıg the last fifteen years, has ripened to a , at which all authorities are agreed as to the sity of making the watershed area the unit of nistration for water supply (among other sub-),[*] and I am of opinion that, for the purposes ater supply, there should be districts and sub- icts, formed by (†) the grouping and (‡) the ivision of these units.

.) *Illustration of Grouping on a large scale (an me instance).*—(1.) On the east coast and else- re, there are several small basins containing e and growing towns, such as Colchester, sup- l from wells sunk in the chalk (and tertiary ta), whose gathering ground is at its outcrop, s to the west, and which has a well-known nsive range. There are numbers of these little ns east of the chalk range, which form a ıral group from the southern limit of the ımes basin to the Wash. The same *régime* ob- ıs to the coast of Lincolnshire and of Yorkshire. several basins draw upon a common source, should exhaust their resources upon one prin- le, and subject to Watershed Boards ; [§] the ad- ıistrative machinery should be so designed as to nit of their doing so. If it ever becomes neces- y for them to look further west, an extended plication of the powers conferred upon the Local vernment Board [38 and 39 Vict., c. 55, 270, 279] alter the boundaries,[‖] effect the union of dis- cts, and to enable one to supply another [38 and Vict., c. 55, 61] would be necessary. This is ven as an extreme instance of a case that may ten arise, and in explanation of many of the ovisions suggested below, all of which are exten- ons of powers already contained in Acts of Par- ament.

(iii.) *Subdivision.*—Subdivision of basins would llow Clause 33 of the Rivers Conservancy Bill, 379.

C.—WATERSHED BOARDS.

I therefore suggest again, what has often been uggested before by others, viz., the creation of Vatershed Boards, to deal with the question of vater supply, subject to the constitution, control, nd restrictions, and with the powers and duties, uggested below.

D.—COMMISSIONERS' DISTRICTS.

(*a.*) *Commissioners' Districts.* — England and Wales are mapped out into three Commissioners' districts, and these three districts are further divided into (*b.*) Sub-Commissioners' districts, each consisting of aggregates of watershed basins, administered by Watershed Boards. (*a.*) The north of England is made one Commissioner's district, as shown on the map[¶]; the Midland Counties and Wales another;[**] and the Southern Counties a third,[††] on the principle that the rivers flow east and west, and the mountains and geological lines run north and south. By this arrangement, each Commissioner's district gets its full share of mountain, plain, and geological strata. Again, the three localities of highest rainfall, the lake mountains, the Welsh mountains, and Dartmoor, accord well with these divisions, each of which gets its share of the wettest and driest areas.

(*b.*) *Sub-Commissioners' Districts.*—The Sub-Commissioners' districts are formed by dividing each of the east and west belts, or zones, formed by the the three Commissioners' districts, into two parts, separated by the north and south backbone watershed lines, in the Northern and Midland districts, and the southern limit of the Thames basins as far as, and then along, the western limit of the Arun basin, in the Southern districts.

E.—RAINFALL.

The rainfall of the Commissioners' and Sub-Commissioners' districts is made to appear upon the accompanying map; and is also stated in detail in Tables 1 and 3 of Appendix B[*], the authority in each case, of course, being Mr. Symons.

F.—GEOLOGY.

As the areas of administration of the proposed Watershed Boards have to be determined, not by these essays, but by the inhabitants of the several watersheds, I have arranged the 215 watersheds given on the ordnance map into 36 natural groups, each of which groups stands so related to the watershed basins contained in it, that a statement of the rainfall and geology of the group applies to every basin within the group. Several of these groups are single basins. The groups are only for the purpose of illustrating the geology and rainfall of the basins, and are not suggested "districts."

G.—POPULATION.

Table 2, Appendix B, shows the population of each Sub-Commissioner's district, and of each county and part of county in the district.

The population of the suggested Watershed Boards' districts cannot, I take it, be stated until the populations have determined the districts. What may be the least area and the least population capable of managing its own water supply would be difficult questions to answer; and, I doubt not, that any suggested appointment of favourite gathering grounds would prove unacceptable to the interests most affected. For instance, the Dee falls into a natural group with the populous basin of the Mersey, and if the matter could have been prescribed, the Dee basin would long ago have supplied the Mersey basin.

This essay suggests the creation of facilities for establishing Watershed Boards, on the lines of the Rivers Conservancy Bill, but does not go so far as to prescribe the areas of these districts, which will all have to be fought for.

H.—CONSTITUTION OF WATERSHED BOARDS.

(i.) *Respecting the Claims of Boards of Guardians to be represented on the Boards.*—Though much abuse has been hurled at Boards of Guardians since their erection into rural sanitary authorities, it is certain that the remedies for the evils complained of have neither been cheap, nor easily applied in many cases; and the Boards were ably defended by Dr. Syson, at the Congress on National Water Supply, 1878.[*] He says:—

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[*] 1. Report Roy. San. Com., 1869, p. 39. 2. Lord Robert Montagu, p. 339. 3. Report of Roy. San. Com. on R. Clyde, 1876, pp. xxvii., xxviii. 4. Report Conservancy Boards Committee House of Lords, 1877, pp. iv., v. 4*a*. Rivers Conservancy Bill, 1879. 5. And numerous private authors.

[†] Rivers Conservancy Bill, clauses 37, 40.

[‡] Rivers Conservancy Bill, clause 33.

[§] Report Roy. San. Com., 1869, p. 39.

[‖] Rivers Conservancy Bill, 1879, clauses 39, 40.

[¶] 1. Northern Commissioner's District,

[**] 2. Midland Commissioner's District.

[††] 3. Southern Commissioner's District.

[*] Appendix B., Tables 1 and 3.

> "They ought to elevate Boards of Guardians and sanitary authorities, by entrusting them with more power. He believed local sanitary authorities in the country had done their duty very fairly, and, to a certain extent, bravely; but the great obstacle was the Local Government Board, which would not allow them to work without such an amount of red tape that they dare not attempt it."

Both evidently being in the same dilemma, not knowing what to do.

Mr. Vigers, a member of a rural sanitary authority, or Board of Guardians, having direction of a union of 44,406 acres, with a population of 22,949 persons, including several perfectly rural districts, says[†]:—

> "The district was managed by a Board, sitting once a fortnight, and the representatives who formed the Board had as much sympathy with each other as could well be imagined. Those who represented the rural districts came there, apparently, for the express purpose of resisting any proposal which appeared to involve expenditure of money, so that anything which was proposed for the benefit of the towns and villages was swamped at once. There was not a sufficient number of Guardians who took interest in any plans of improvement." . . . . "His own opinion was" . . . . "that instead of similar matters being left in the hands of Boards of Guardians, there should be a Board elected by the owners of property in the several districts."[‡]

He then quotes from Mr. Michael's paper:—

> "'Whatever may be the character and ability of Sanitary Boards, it is upon the ability and character of their officers that success must depend.' He thoroughly endorsed that remark. It was utterly impossible for a Board of Guardians, meeting only once a fortnight, to even partially master the difficulties with which they had to deal."

Now, as many Boards of Guardians appear to be provided with a sanitary officer, who is not paid to devote his whole time to his work, it is not likely that he, any more than they, will be able to grapple with difficulties which have baffled the Local Government Board, with all its scientific appliances. It is true there is a scientific staff attached to that Board, but it is too lofty, and out of the reach of rural sanitary authorities. I submit, therefore, that the case of incapacity against Boards of Guardians is not proven, for whatever proves them to be incapable proves equally the inefficacy of the antidote in the Local Government Board.

Interests Represented on Watershed Boards.	*How Represented.*
Urban Sanitary Authorities.	One or more elected member.
Rural ” ”	” ” ”
Owners and occupiers of land.	As in Rivers Conservancy Bill.
Town Councils.	As in Public Health Act, 1875 [38 and 39 Vic., c. 55, 6].

I therefore suggest that one or more representatives from each Board of Guardians within the watershed area should sit upon the Watershed Board, according to the rateable value of the property within that part of the union lying within the watershed area.

2. *As to the Representation of Landowners.*—That the landowners be represented in a manner similar to that adopted in the Rivers Conservancy Bill, 1879, now before the House of Lords, as modified below. Clause 6 of that Bill meets all requirements for the formation of Watershed Boards for water supply, as far as regards sanitary authorities and landowners.

3. *As to the Representation of Towns.*—In any Watershed Board for water supply, however, towns must be represented. I would add to the above constituents Town Councils, represented in proportion to rateable value of property within their districts.

4. *Miscellaneous Suggestions bearing on the Constitution of Watershed Boards.*—The only suggestions I have discovered bearing on the difficult question of the constitution of watershed authorities—upon which the extent of the area of administration to a certain extent depends—are those contained in the paper of Lord Robert Montagu on Watershed Boards;[*] in Sir John Hawkshaw's report on the Clyde;[†] and in the parallel case of the Rivers' Conservancy Bill, 1879.

J.—THE LOCAL GOVERNMENT BOARD AS A CENTRAL AUTHORITY.

It seems to commend itself that the Local Government Board should remain a central authority, to which Watershed Boards, under the wing of their several Commissioners should be affiliated.

K.—COMMISSIONERS OF WATERSHED BOARDS.

The Local Government Board being above the three Commissioners, would then act not only as a Court of Reference and of Appeal, but would, by presiding in common over all the affiliated Watershed Boards, secure "uniformity of action."[‡] Sir John Hawkshaw, in his report on the Clyde,[§] in recommending the appointment of Commissioners of the Clyde, having jurisdiction over the whole basin, rightly estimates the value of this, for he recommends similar Commissions for all other basins, "with an officer in common, to secure uniformity of action."[‖] For "an officer in common," whose position would be far from enviable, I would interpose the Commissioners, leaving the Local Government Board, with their scientific staff, just as it is.

L.—AS TO THE APPOINTMENT OF AN ENGINEER AND STAFF TO WATERSHED BOARD.

Now, as Mr. Vigers and Mr. Michael remark, it it is upon the character and ability of the officers of the Board that success must depend, and it is necessary that the whole time of those officers should be given to their work. Again, since the scientific staff of the Local Government Board is too small to give constant, detailed, and comprehensive attention to all parts of the 37,319,221 acres in England and Wales, and of too lofty a description to do drudgery for Watershed Boards, and not possessed of the necessary scientific knowledge of the hydrogeology of England and Wales, and from being formed for, and employed upon, other work, I think that each Watershed Board should have its own engineering, but not scientific staff.*

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[*] Congress on National Water Supply, 1878. Disc., p. 9.

[†] "The Working of the Sanitary Acts in Rural Districts," by W. H. Michell. Trans. Inst. Surveyors, vol. viii., p. 363.

[‡] "Sedgwick," pages 390, 398.

[*] Lord Robert Montague, paper on "Watershed Boards." Report Royal Sanitary Commission, p. 347.

[†] Sir John Hawkshaw, report on Pollution of Clyde, p. xxviii. Public Health Act, 1875 [38 & 39 Vict., c. 55, 6].

[‡] Letter on Watershed Boards, Lord Robert Montagu, Royal Sanitary Com., p. 347. The Working of the Sanitary Acts in Rural Districts, W. H. Michael, Transac. Inst. Surveyors, vol. viii. p. 375.

[§] Report of Royal Com. on R. Clyde.

[‖] P. xxix.

M.—SUGGESTIONS RELATING TO AREAS AND BOUNDARIES, AS PART OF A BILL TO MAKE PROVISION FOR THE ADMINISTRATION OF WATER SUPPLY.—ADAPTED WITH MODIFICATIONS FROM THE RIVERS CONSERVANCY BILL.

Preliminary.

1. This Act may be cited as the Watershed Boards Act.

2. This Act shall not extend to Scotland or Ireland.

Proceedings for establishing Watershed Board.

3. The Local Government Board may, on application, and after local inquiry, and with the sanction of Parliament, establish a local Watershed Board, for the administration of water supply, in a district consisting of the whole or any part of the basin of the river, or the basins of the rivers.

The application may be made by any ten or more owners of land, of an aggregate rateable value of one thousand pounds, within the basin or basins, or by any sanitary or municipal authority whose district is wholly or partly within the basin or basins.

The application shall describe, by reference to a map or otherwise, the district for which it is proposed that the Watershed Board be established, and shall be in such form, and contain such particulars, and be accompanied by such information as the Local Government Board from time to time require.

4. The Local Government shall take into consideration any application made to them for the establishment of a Watershed Board, and, on being satisfied that a *prima facie* case has been made out for the establishment of the Board, and that sufficient provision has been made for the expenses which may be be incurred by the Local Government Board in connection with any local inquiry directed under this section, shall direct one of their inspectors to hold a local inquiry as to the expediency of establishing a Board, and as to the limits which should be assigned for the district of the Board.

Notice of the inquiry shall be given by advertisement and otherwise as the Local Government Board direct.

5. (1.) If after the local inquiry it appears to the Local Government Board expedient that a Watershed Board should be established for the proposed district, or for any part of the proposed district, with or without, in either case, the addition of any adjacent area, the Local Government Board shall prepare a draft provisional order for the establishment of the Watershed Board, defining the limits of the district, specifying the lands, if any, excepted from the district, and the lands, if any, exempted from the rates of the board, declaring the number, and (subject to the provisions of this Act) the constitution of the Watershed Board.

(2.) The Local Government Board shall cause printed copies of the draft provisional order to be deposited with the clerks of the several sanitary authorities for districts wholly or partly comprised in the district defined by the draft order, and the copies so deposited shall be open to inspection, without fee, by all owners of land and ratepayers within that district. The Board shall also cause notice to be published of the deposit and of the time and place, or times and places, at which one of their inspectors will attend to hear any objections to the draft order.

(3.) After receiving the report of their inspector with respect to the draft order, the Local Government Board may, subject to the provisions of this Act, make the provisional order, with such additions and modifications as to them seem expedient. but the order so made shall not be of any validity until it is confirmed by Act of Parliament.

Constitution of Watershed Board.

6. (1.) A Watershed Board shall consist of life members and elective members.

(2.) Life members shall be in the first instance named in the order establishing the Board.

(3.) Elective members shall be elected from time to time by the sanitary authorities, for districts wholly or partly within the district of the Board, and each sanitary authority shall elect at least one member.

(4). The life members shall not be less than one-third of the total number of members of the Board. Each life member must be qualified, by being the owner of land within the district of the Board, of an annual rateable value of three hundred pounds. He shall, subject to the provisions of this Act, be entitled to hold office for life. On his office becoming vacant, the vacancy shall, as soon as may be, be filled by the Board.

(5.) The elective members, or, if more than one member is elected by any authority, then not less than one-half of the members elected by that authority, must be severally qualified by being owners of land within the district of the Board of an aggregate rateable value of one hundred pounds. The elective members not so qualified must either be, or be qualified to be, members of the authorities by whom they are severally elected. The term of office of each elective member shall be three years, but he may, if qualified, be re-elected.

7. (1.) On the passing of the Act confirming an order for the establishment of a Watershed Board, and within the time, if any, limited by the order, the Board shall be formed in manner directed by the order.

(2.) A Watershed Board, when formed, shall be a body corporate bearing the name given to it by the order by which it is established, with perpetual succession and a common seal, and having power to hold land for the purpose of this Act without any licence in mortmain.

Miscellaneous Provisions.

A Watershed Board may divide their district into sub-districts, consisting of areas drained by any tributary stream or streams flowing into any river within their district, and may from time to time alter the boundaries of any such sub-district.

A Watershed Board may, from time to time, appoint out of their own number as many persons as they think fit, for any purposes of this Act which in the opinion of the Board would be better regulated and managed by means of a committee. But a committee so appointed shall in no case be authorised to borrow any money, to make any rate, or to enter into any contract, and shall be subject to any regulations and restrictions which may be imposed by the Board, &c., &c.

Every Watershed Board shall make an annual report, in such form and at such time as the Local Government Board from time to time direct, of all works executed, and of all sums received and disbursements made by them under and for the purposes of this Act during the preceding year, and shall send a copy to the Board, and publish another copy in some local newspaper circulating in their district.

A Watershed Board may be established for, and its district may include the basins of, two or more rivers.

The Local Government Board may from time to time, by provisional order, alter the boundaries of a Watershed Board district, and adjust any rights or liabilities affected by the alteration.

The Local Government Board may from time to time, by provisional order, on the application of any two or more Watershed Boards, dissolve them as separate Boards, and reconstitute them as a single Board for a district consisting of the districts of the former boards, and make such provisions as to the mode of constituting the new Board as may be necessary or expedient for that purpose.

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* National Water Supply Congress, Sir H. Cole, p. 30; Joseph Parry, p. 58.

Thereupon, subject to any special provisions contained in the order, the rights, powers, estates, and property vested in the old boards shall vest in the new board, and all the liabilities and obligations of the old boards shall be borne by the new board, and the old boards shall be discharged from all such liabilities and obligations, and the new board shall be deemed to be the successors of each of the old boards.

Any sanitary authority appointed, or acting by or under any Act of Parliament for any district comprised wholly or partially within the district of a Watershed Board, whether the powers of the authority under the Act do or do not extend beyond the district of the Watershed Board, may, if it seems to them expedient, at a meeting called for that purpose, transfer to the Watershed Board, with the consent of that Board, but not otherwise, all the rights, powers, estates, property, and liabilities of the authority under the Act or otherwise, &c.

N.—Resume.

We should thus have Watershed Boards established over one or more river basins, by provisional order of the Local Government Board, after due local enquiry, upon application, of landowners, sanitary authorities, or towns, situated within the watershed basin, or basins.

O.—Miscellaneous Considerations Tending to the Establishment of Watershed Boards.

There can be no doubt that if the dual interests of town and country, as above suggested, were brought under the operation of one Board, the matter would work well and quickly.

For sundry reasons connected with rating, taken in connection with the accepted principles[*] of (1) the expediency and advantage of consolidating the water supply under public control; (2) the advantage of making it embrace large areas, especially in reference to the groups of towns in manufacturing districts; and (3) the encouragement given to small towns and rural districts by the provision[†] recently applied in the case of the Thirlmere scheme, that places along the line of an aqueduct may be supplied therefrom. Towns as well as country districts would seek the establishment of Watershed Boards.

P.—As to Advisability of Interposing Commissioners between Watershed Boards and the Local Government Board.

Now, from the very large number of Watershed Boards (even when reduced to a possible minimum by grouping, of about 51) it would appear expedient to interpose between them and the Local Government Board, a Commission of three, composed in the following manner:—

1. A Commissioner of the Northern Boards. 2. A Commissioner of the Midland Boards. 3. A Commissioner of the Southern Boards.—Each having charge of the district shown on the accompanying map.

Q.—Province of the Three Commissioners.

The province of the three Commissioners would be—(1), To answer inquiries by the Local Government Board, respecting their large districts; (2), To make annual reports to the Local Government Board; (3), To be consulted by the Watershed Boards in their districts, and to confer with them and aid them in their deliberations upon the merits of new schemes, the pollutions of underground waters, and other questions.

R.—Duties of Watershed Boards.

The duties of the Watershed Boards would be—(1), To conserve the interests of the water systems underground, and to remove causes of pollution by cesspools, dry wells, &c.; (2), To hear complaints from any part of their district, as to deficient water supply, and, if they deem proper; (3), To advertise for competing schemes for supplying the part of their district in need of water; (4), To examine, with the aid of their Commissioner, the schemes propounded, so as to determine whether all local sources have been tapped, and if satisfied with any of them, to pass it to their Commissioner, with instructions to forward it to the Local Government Board, who may, if they please, order any further inquiry; (5), To veto any scheme which does not pass the examination by themselves, in concert with their Commissioner;[*] (6), To enforce the due performance of the provisions of the parts of the Public Health Act, 1875,[†] relating to water supply and the Public Health (Water) Act, 1878; (7), To levy rates; (8), To report annually to their Commissioner, who would make general report to Local Government Board.

S.—Powers of Watershed Boards.

They should be empowered[‡] to purchase lands, purchase or construct waterworks and reservoirs; to put water into them[§] when made; and to distribute water within their district, &c., &c.[‖]

T.—Duties of Sub-commissioners.

Each of the three Commissioners should have a staff composed of two Sub-Commissioners, who would assist him in his duties in the Sub-Commissioners' districts, shown on the accompanying map, with such other temporary or permanent assistance as they might require.

U.—President of Local Government Board to retain present functions after establishment of Watershed Boards, &c.

Finally, at the head of all would be the President of the Local Government Board,[¶] who would answer in Parliament all questions connected with water supply.[**]

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[*] Royal Commission on Water Supply, 1869, Part V., Sec. IV., § 246, 248, and pp. cxxii-cxxiii. Royal San. Com., Report, p. 8, Observations, pp. 15-16. Royal Com. on Water Supply, § 263, p. cxxvii; § 264, p. cxxviii. Do., do., Part VI., § 256, p. cxxv.

[†] Royal Com. on Water Supply, 1869, Part VI., § 255, p. cxxv. 6th Report Rivers Pollution Commission, p. 430. Report of Select Committee on Public Health Act (1875) Amendment Bill, 1878, Part IV., § 17. p. vii. National Water Supply Congress papers, J. F. Bateman, J. W. W. Bund, E. Frankland.

[*] Royal Sanitary Commission 1869 report, p. 39.

[†] 38 & 39 Vict., c. 55, 62.

[‡] 38 c., 39 Vict., c. 55, 51, 52.

[§] National Water Supply Congress, Disc., De Rance, p. 8.

[‖] 38 & 39 Vict., c. 55, 51, 63.

[¶] Royal Sanitary Commission, 1869, Report, p. 26. Rivers Conservancy, British Association, Easton, p. 21.

[**] Report of Royal Sanitary Commission, 1869. Paper on Watershed Boards (Lord Robert Montagu), p. 347.

V.—AS TO APPOINTMENT OF COMMISSIONERS.

The three Commissioners should be appointed by the Crown (and not by the Local Government Board), but they would hold permanent office. The six Sub-Commissioners should also be appointed by the Crown, with permanent office. In the Watershed Boards the elective members would hold office for three years, but would be eligible for re-election.[*]

W.—GENERAL VIEW OF THE ADVANTAGES OF THE SUGGESTED ARRANGEMENT.

The advantages of this arrangement would be that (1) the areas administered by Watershed Boards would be large enough to be properly dealt with, which the existing areas are not; (2) that the Watershed Boards would have the Commissioners and Sub-Commissioners resident in their districts, familiar with their wants, working with them, and, for this reason, having amongst them the very highest scientific attainments and knowledge (for the qualifications of a Commissioner should be a high one)[†] accessible, without an amount of red tape that now renders the scientific staff of the Local Government Board to a great extent useless to country districts;[‡] (3) that it would be to the interest of the Commissioners to see water supply properly carried out, whereas at present nobody but the engineer who prepares the plans and carries out the work cares anything about it. (4) That the Local Government Board[§] would have nothing to do with it, beyond granting provisional orders, and perhaps, in rare instances, putting their veto on some scheme. (5) The people would find out, and gladly, that they were acting for themselves, carrying out their own schemes of improvement in water supply, and without the depressing sense of the existence of a superior authority immediately above them, always ready to press them rather faster than they are inclined to move, a state of things which has produced a deadlock with the Local Government Board[||] (which was intended to be the mainspring of action) and local authorities. (6) That in the rare cases in which the Local Government Board may refuse a provisional order, the action is not direct, but there is the Commissioner as a cushion in between to bear the brunt,[¶] and who, doubtless, will be well paid to bear it.[**]

X.—CONCLUSION.[††]

Thus the real mainspring in the provision of knowledge by the Hydro-Geological Survey, and the independent co-operation of the Watershed Boards with their Commissioners, would, no doubt, soon produce the good result of placing the water supply of the country in a satisfactory state.[‡‡] But there is a great deal to be done, not the smallest part of which is the education of the people themselves in sanitary subjects.[§§] When will they learn that it is cheaper to pay for pure water, than for the father of a family to be killed by a fever, generated by drinking the polluted water of his own well, and, may be, leave ten or a dozen weakly children, from the same cause, dependent upon the poor-rates?

The scheme which I have the honour to suggest is the natural outcome of the progress of popular opinion during the last fifteen years; and, if there is not any original suggestion in the paper, the combination is, perhaps, new, and ought, at least, to work satisfactorily. It is not by any one great effort that the *vis inertiæ* is to be overcome, but by the constant dropping which suggests my motto, —*Gutta cavat lapidem, non vi, sed sæpe cadendo.*

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[*] Rivers Conservancy Bill, clause 6.

[†] National Water Supply Congress. disc. (Dr. Syson), p. 9.

[‡] National Water Supply Congress. Papers (F. R. Conder), p. 40.

[§] Royal Sanitary Commission, 1869, report:—The central authority recommended (which proved to be the Local Government Board) "must not take to itself the actual work of local government—should have direction only. It must steer clear of the work on which the General Board of Health was wrecked; for so completely is self-government the habit and quality of Englishmen, that the country would resent any central authority undertaking the duties of the local executive" (pp. 35, 36).

[||] National Water Supply Congress, discussion, G. W. Child, p. 7.

[¶] Report Royal Sanitary Commission, 1869, letter on Watershed Boards, Lord Robert Montague, p. 340.

[**] The Working of the Sanitary Acts in Rural Districts, W. H. Michael, Transac. Inst. Surveyors, Vol. viii., p. 375 (lines 26 to 33)

[††] National Water Supply, discussion, Lucas, Clutterbuck, Chadwick, C.B., Conder (pp. 2, 3): Child (p. 4), Shelford, Bond, De Rance (p. 5; ditto papers—Bund (p. 30), Child, Clutterbuck (p. 38), Conder (p. 40), Bailey Denton (p. 44), De Rance (p. 45), Homersham (pp. 52, 53), Lucas (p. 55), Parry (57), Prestwich (pp. 62—66), Shelford (p. 66), Seymour (pp. 70—72).

[‡‡] Royal Sanitary Commission, 1869 report, and authorities too many to enumerate.

[§§] The working of the Sanitary Acts, &c. Michael. P. 376,

APPENDIX A.

NATURE OF EVIDENCE.	LIST OF AUTHORITIES.	DATE.
REPORTS:—		
Royal Commissions	Royal Commission on Water Supply	1869
	Royal Sanitary Commission	1869
	Pollution of Rivers Commission, 6th Report	1874
	River Clyde Pollution.	
Parliamentary Committees	House of Lords:—	
	Conservancy Boards Committee	1877
	House of Commons:—	
	Thames Floods Prevention	1877
	Public Heath Act, 1875, Amendment Bill	1878
ACTS OF PARLIAMENT:—		
[34 & 35 Vict. c. 70]	Local Government Board Act	1871
[38 & 39 Vict. c. 55]	Public Health Act (1875)	1875
[41 & 42 Vict. c. 25]	Public Health (Water) Act	1878

APPENDIX A.—(*Continued.*)

NATURE OF EVIDENCE.	LIST OF AUTHORITIES.	DATE.
BILLS IN PARLIAMENT	Rivers Conservancy Bill	1879
	County Boards Bill	1878 and 1879
CONGRESSES	National Water Supply, Society of Arts	1878
	Rivers Conservation, British Association	1878
TRANSACTIONS OF INSTITUTIONS:— Papers	"The Working of the Sanitary Acts in Rural Districts" (Trans. Inst. Surveyors, vol. VIII., p. 363.)	1876
	"County Boards" .. .. (*Ibid*, vol. x., p. 151.)	1878
MISCELLANEOUS	Digest of the English Census of 1871, by James Lewis ..	
	Symons's Rainfall Maps, &c.	
	Geological Maps—various.	

APPENDIX B.

TABLE 1.

1.—DISTRICT OF THE COMMISSIONERS OF NORTHERN BOARDS.

(*a.*) *Western Sub-Commissioner's District.*

Name of Watershed.	No. on Ordnance Map.	Area (sq. miles).	Group.	No. of Watersheds.	Mean Rainfall.		Geology.
					Mean Range.	Inches.	
1. Several small streams ...	vi	21	1	5	30 to 75	41·17	New Red Sandstone, Permian, millstone grit, carboniferous limestone, Silurian.
2. Line	vii	104					
3. Eden	xix	915					
4. Wampool...	xiv	78					
5. Waver	xv	70					
6. Ellen	xvi	72	2	7	30 to 75	41·17	Coal measures, millstone grit, carboniferous limestone, and a little Permian on coast.
7. Derwent	xviii	262					
8. Several small streams ...	xvii	11					
9. Ehen	xxv	72					
10. Calder	xxvi	28					
11. Irt	xxvii	61					
12. Esk	xxviii	64					
13. Several small streams ...	xxxi	28	3	7	25 to 75	41·17	The same as Group 2.
14. Duddon	xxix	46					
15. Several small streams ...	xxxii	56					
16. Leven	xxx	202					
17. Kent	xxxiii	255					
18. Lune	xxxiv	418					
19. Wyre	xli	208					
20. Ribble	xlii	585	4	4	25 to 75	41·17	New Red Sandstone, coal measures, millstone grit, &c.
21. Small stream	xlv	7					
22. Douglas	xlvi	168					
23. Several small streams ...	xliv	55					
24. Alt	xlvii	126	5	4	25 to 75	38·74	New Red Sandstone, Permian, coal measures, millstone grit, carboniferous limestone, and Silurian.
25. Mersey	xlviii	885					
26. Weaver	lxxi	711					
27. Dee	lxx	818					
28. Clwyd	lxix	319	6	17	40 to 75	...	Cambrian and Silurian, with carboniferous limestone in Anglesey.
29. Several small streams ...	lxviii	89					
30. Conwy	lxvii	222					
31. Several small streams ...	lxi	78					
32. Seiont, Gorfai, &c. ...	lxii	143					
33. Soch	lxiii	33					
34. Erch	lxiv	55					
35. Dwyfach and Dwyfawr ...	lxv	48					
36. Prysor	lxvi	141					
37. Artro	lxxv	45					
38. Small streams	lxxvi	3					
39. Mawddach	lxxvii	151					
	Mainland	7,598					
ANGLESEY.							
40. Braint	lx	53					
41. Cefni	lix	41					
42. Several small streams ...	lvii	69					
43. Alaw	lvi	58					
44. Several small streams ...	lviii	47					
	Anglesey	268					
Total, with Anglesey ...	...	7,866		44			

Appendix B.—(*Continued.*)

(*b.*) *Eastern Sub-Commissioner's District.*

Name of Watershed.	No. on Ordnance Map.	Area (sq. miles).	Group.	No. of Watersheds.	Mean Rainfall.		Geology.
					Mean Range.	Inches.	
1. Tweed (part of)	i	37	1	10	25 to 50	41·17	Coal measures, millstone grit, and carboniferous limestone, with some intrusive or trap rocks.
2. Till	ii	231					
3. Several small streams	iii	129					
4. Aln	iv	104					
5. Coquet	v	240					
6. Several small streams	x	18					
7. Several small streams	xi	37					
8. Wansbeck	ix	126					
9. Blyth	xii	131					
10. Several small streams	xiii	31					
11. Tyne	viii	1,130	2	1	25 to 50	41·17	Coal measures, millstone grit, and carboniferous limestone.
12. Wear	xx	456	3	1	25 to 50	41·17	Permian, coal measures, millstone grit, and carboniferous limestone.
13. Several small streams	xxi	77	4	2	25 to 50	41·17	Oolite, Lias, New Red, coal measures, millstone grit, carboniferous limestone.
14. Tees	xxii	708					
15. Several small streams	xxiii	100	5	2	25 to 50	41·17	Oolite and Lias.
16. Esk	xxiv	147					
17. Ouse	xxxv	1,842	6	3	25 to 50	30·88	Oolite, Lias, New Red Sandstone, Permian, coal measures, millstone grit, and carboniferous limestone.
18. Aire and Calder	xliii	815				30·88	New Red, Permian, millstone grit, and carboniferous limestone.
19. Don	xlix	682					
20. Derwent	xxxvi	794	7	1½	25 to 50	30·88	Chalk, Oolite, Lias, New Red Sandstone.
21. Several small streams	xxxvii	157					
22. Hull	xxxviii	364	8	3½	25 to 50	30·88	Post tertiary, chalk, Oolite, Lias, and New Red Sandstone.
23. Foulness	xxxix	133					
24. Several small streams	xl	206					
Eastern Sub-Commissioner's District		8,695		24			
44. Western Sub-Commissioner's Districts		7,866					
68. Total area under Commissioner of Northern Boards		16,561					

District of the Commissioner of Midland Boards.

Western Sub-Commissioner's District.

Name of Watershed.	No. on Ordnance Map.	Area (sq. miles).	Group.	No. of Watersheds.	Mean Range.	Inches.	Geology.
1. Dysynni	lxxviii	64	1	12	40 to 75	...	Silurian.
2. Afon Dyfi	lxxix	217					
3. Lery	lxxx	34					
4. Stream	lxxxi	24					
5. Rheidol	lxxxii	70					
6. Tstwyth	xcviii	75					
7. Wyrai	xcix	23					
8. Arth	c	31					
9. Aeron	ci	52					
10. Several small streams	cii	48					
11. Teifi	ciii	386					
12. Nevern, Gwaen, &c.	civ	94					
13. St. Bride's Bay	cv	65	2	14	40 to 75	46·15	Coal measures, millstone grit, carboniferous limestone, Old Red Sandstone, Silurian, with a little Oolite, and New Red Sandstone (cxx and cxviii).
14. E. and W. Cleddau	cvi	212					
15. Pembroke	cvii	114					
16. Several small streams	cviii	61					
17. Taf	cix	183					
18. Towy	cx	514					
19. Gwendraeth-fach Gwendraeth-fawr	cxii	73					
20. Llwchwr	cxiii	156					
21. Small stream	cxiv	66					
22. Tawe	cxv	106					
23. Neath	cxvi	118					
24. Afon	cxvii	87					
25. Ogmore	cxviii	114					
26. Several small streams	cxx	67					
27. Ely	cxxi	81	3	7	25 to 75	...	Oolite, New Red Sandstone, coal measures, millstone grit, carboniferous limestone, Old Red Sandstone, and Silurian.
28. Taff	cxix	198					
29. Rumney	cxxii	94					
30. Ebwy	cxxiii	94					
31. Usk	cxxiv	540					
32. Several small streams	cxxv	55					
33. Wye	cxi	1,609					
34. Severn	lxxxiii	4,350	4	1	25 to 75	...	Oolite, Lias, New Red Sandstone, Permian, coal measures, millstone grit, carboniferous limestone, Old Red Sandstone, and Silurian.
		10,075		34			

Appendix B.—(*Continued.*)

Eastern Sub-Commissioner's District.

Name of Watershed.	No. on Ordnance Map.	Area (sq. miles).	Group.	No. of Watersheds.	Mean Rainfall.		Geology.
					Mean Range.	Inches.	
1. Trent	lxxii	4,052	1	1	25 to 50	30·88	Oolite, Lias, New Red Sandstone, Permian, coal measures, millstone grit. carboniferous limestone.
2. Ancholme	l	244	2	6	25 to 50	30·88	Oolite and chalk (Ancholme) chalk, and post tertiary.
3. Several small streams ...	li	122					
4. Several small streams ...	lii	39					
5. Lud	liii	139					
6. Withern Eau	liv	189					
7. Steeping	lv	101					
8. Witham	lxxiii	1,079	3	1	25 to 50	29·11	Oolite, chalk, and fen.
9. Welland	lxxiv	760	4	2	25 to 50	29·11	Oolite and fen.
10. Nen	lxxxiv	1,077					
11. Ouse	lxxxv	2,607	5	4	25 to 50	29·11	Chalk gault, lower greensand, Oolite, Lias, and fen.
12. Wissey	lxxxviii	243					
13. Nar, or Setchy	lxxxvii	181					
14. (lxxxvi) part of	lxxxvi	abt. 93					
		10,876		14			
34. Western Sub-Commissioner ...		16,075					
48. Total area under Commissioner of Midland Boards		20,951					

District of the Commissioner of Southern Boards.

Western Sub-Commissioner's District.

1. Avon	cxxvii	891	1	2	25 to 40	...	Oolite, Lias, carboniferous limestone, and New Red Sandstone.
2. Yeo	cxxvi	106					
3. Axe	cxlv	101	2	7	25 to 40	...	Oolite, Lias, New Red Sandstone, and Devonian.
4. Brue	cxlvi	197					
5. Several small streams ...	cxlvii	80					
6. Perret	cxlviii	562					
7. Small stream	cxliii	82					
8. Small stream	cxlii	24					
9. Small stream	cxli	29					
10. East Lynn	cxl	41	3	5	40 to 75	...	New Red, carboniferous limestone, Devonian, granite (Dartmoor).
11. Small streams	cxxxvii	47					
12. Jaw	cxxxix	455					
13. Torridge	cxxxviii	336					
14. [Bideford Bay]	clxxxv	10					
15. [Bude Bay]	clxxxvi	108	4	7	40 to 50	...	Carboniferous and Devonian, with some granite.
16. [Pentire Point]	clxxxviii	8					
17. Alan or Camel	clxxxix	149					
18. Several small streams ...	cciii	154					
19. Small streams	ccix	43					
20. St. Ives	Not numbered						
21. Small streams	ccvii	47					
22. Several small streams ...	ccviii	40					
23. Several small streams ...	ccx	29	5	11	40 to 50	...	Same as Group 4, without carboniferous.
24. Small streams	ccxv	33					
25. Small streams	ccxiv	10					
26. Small streams	ccxiii	33					
27. [Falmouth]	ccxii	12					
28. Small stream	ccxi	40					
29. [Truro]	cciv	66					
30. Fal	ccv	50					
31. Several small streams ...	ccvi	80					
32. Fowey	cxc	120					
33. Several small streams ...	cxci	71					
34. Lynher	cxcii	100	6	9	40 to 75	...	Carboniferous, Devonian, and granite (Dartmoor).
35. Tamar	clxxxvii	385					
36. Tavy and Wallcombe ...	cxciii	85					
37. Plymouth Leat	cxciv	23					
38. Plym	cxcv	59					
39. Yealme	cxcvi	36					
40. Erme	cxcvii	48					
41. Aune	cxcviii	54					
42. [Start Point]	ccii	78					
43. Dart	cxcix	200	7	4	40 to 75	33·73	New Red, Devonian, carboniferous, and granite.
44. Teign	cc	208					
45. Stream	cci	11					
46. Ex.	cxliv	584					

APPENDIX B.—*Western Sub-Commissioner's District.*—(*Continued.*)

Name of Watershed.	No. on Ordnance Map.	Area (sq. miles).	Group.	No. of Watersheds.	Mean Rainfall. Mean Range.	Mean Rainfall. Inches.	Geology.
47. Otter	cxlix	82	8	7	30 to 40	...	Chalk, Oolite, Lias.
48. Stream	cl	21					
49. Axe	cli	165					
50. Char	clii	39					
51. Brit	cliii	52					
52. Bredy	cliv	21					
53. [Weymouth]	clv	87					
54. Frome	clvi	187	9	4	30 to 40	30·16	Tertiary, chalk, Oolite.
55. Trent or Piddle	clvii	119					
56. Stour	clviii	459					
57. Avon	clix	673					
58. Lymington	clxi	91	10	13	30 to 40	30·16	Tertiary and chalk, with a little upper greensand; gault and lower greensand.
59. Beaulieu	clxii	52					
60. Test	clx	477					
61. Itchen	clxiii	231					
52. Hamble	clxiv	35					
63. ,,	clxv	85					
64. ,,	clxxi	235					
65. ,,	clxxii	26					
Isle of Wight.							
66. [Solent]	clxvi	11					Tertiary, chalk, upper greensand, gault, lower greensand, and Wealden.
67. [Solent]	clxvii	25					
68. Medina	clxviii	28					
69. [Spithead]	clxix	19					
70. South Coast	clxx	51					
Area of Isle of Wight		134	70				
Mainland		9,047					
Total Area Western Sub-Commissioner's District		9,181					

Eastern Sub-Commissioner's District.

Name of Watershed.	No. on Ordnance Map.	Area (sq. miles).	Group.	No. of Watersheds.	Mean Rainfall. Mean Range.	Mean Rainfall. Inches.	Geology.
1. Arun	clxxiii	370	1	9	25 to 40	...	Tertiary chalk, upper greensand, gault, lower greensand, weald clay, and lower Wealden sands.
2. [Worthing]	clxxiv	85					
3. Adur	clxxv	160					
4. [Brighton]	clxxvi	56					
5. Ouse	clxxvii	205					
6. Cuckmere	clxxviii	75					
7. Oldhaven	clxxix	121					
8. Rother	clxxx	312					
9. [Hythe]	clxxxiv	88					
10. Stour	clxxxiii	373	2	3	22 to 31	...	Tertiary chalk and Wealden.
11. Several small streams	clxxxii	157					
12. Medway	clxxxi	680					
13. Cray and Darent	cxxxvi	314	3	3	22 to 31	24·56	Tertiary chalk, upper greensand, gault, lower greensand, Oolite, and Lias.
14. Thames and Lea	cxxviii	4613					
15. Roding, &c.	cxxxiv	317					
16. Crouch	cxxxv	181	4	12	22 to 31	...	Post tertiary, tertiary, and chalk.
17. Blackwater	cxxxi	434					
18. Coast	cxxxii	24					
19. Colne	cxxx	192					
20. Coast	cxxxiii	58					
21. Stour	cxxix	407					
22. Gipping or Orwell	xcvii	171					
23. Deben	xcvi	153					
24. Coast	xcv	32					
25. Ore or Alde	xciv	109					
26. Minsmere	xciii	34					
27. Blyth	xcii	79					
28. Coast (Lowestoft)	xci	53	5	4	22 to 31	...	Post tertiary and chalk.
29. Waverley and Yare	xc	880					
30. Bure	lxxxix	348					
31. Glaven (part of)	lxxxvi	200					
		11,226		31			
Western Sub-Commissioner's district		9,181					
Total under Commissioners of Southern Boards		20,407					

Appendix B.—(*Continued.*)

TABLE 2.

Commissioner of Northern Boards.

Counties.	Population.	
Western Sub-Commissioner :—		
Cumberland (part of)	214,573	
Westmoreland	65,010	
Lancashire	2,819,495	
Yorkshire (part of)	24,934	
Derbyshire (part of)	24,391	
Cheshire	561,201	
Flint	76,312	
Denbigh	105,102	
Carnarvon	106,121	
Anglesea	51,040	
Merioneth (part of)	41,442	
		4,089,621
Eastern Sub-Commissioner :—		
Northumberland	386,646	
Cumberland (part of)	5,680	
Durham	685,089	
Yorkshire (part of)	2,402,512	
Derbyshire (part of)	67,911	
		3,547,838
Total under Northern Commissioner		7,637,459

Commissioner of Midland Boards.

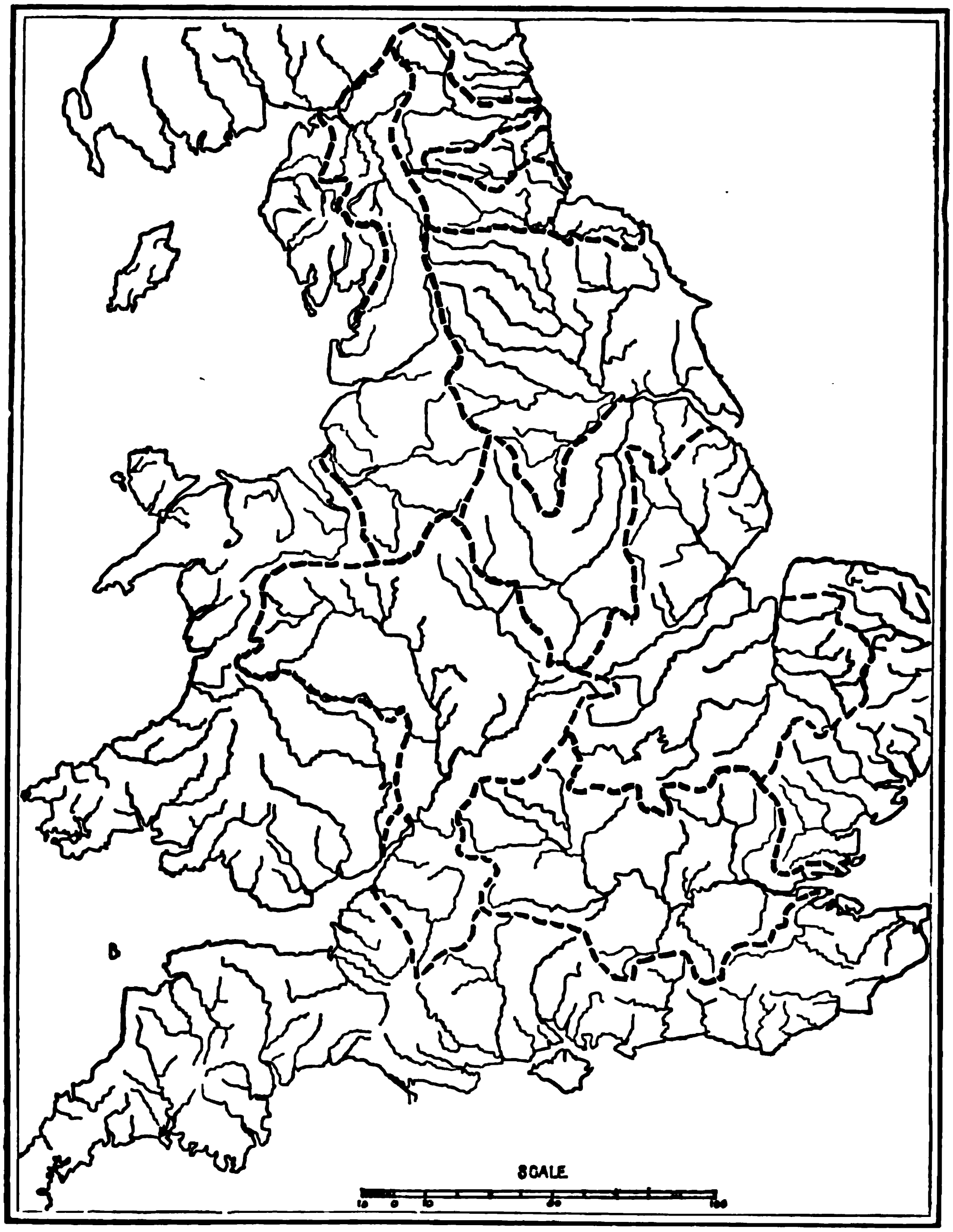
Counties.	Population.	
Western Sub-Commissioner :—		
Merioneth (part of)	5,156	
Montgomery	67,623	
Cardigan	73,441	
Pembroke	91,998	
Caermarthen	115,710	
Glamorgan	397,859	
Brecknock	59,901	
Radnor	25,430	
Shropshire	248,111	
Hereford	125,370	
Monmouth	195,448	
Gloucester (part of)	255,264	
Worcester (part of)	231,376	
Stafford (part of)	90,298	
Warwick (part of)	211,339	
Leicester (part of)	35,317	
Northampton (part of)	4,709	
		2,234,350

Commissioner of Midland Boards.—(Continued.)

Counties.	Population.	
Eastern Sub-Commissioner :—		
Stafford (part of)	768,028	
Worcester (part of)	107,461	
Derby (part of)	287,092	
Warwick (part of)	422,850	
Nottingham	319,758	
Yorkshire (part of)	8,909	
Lincoln	436,599	
Leicester (part of)	233,994	
Rutland	22,037	
Northampton (part of)	230,877	
Oxford (part of)	1,140	
Buckingham (part of)	64,648	
Bedford (part of)	114,240	
Huntingdon	63,708	
Hertford (part of)	32,635	
Cambridge	186,906	
Norfolk (part of)	91,092	
Suffolk (part of)	44,575	
Essex (part of)	16,152	
		3,452,737
Total under Midland Commissioner		5,687,087

Commissioner of Southern Boards.

Counties.	Population.	
Western Sub-Commissioner :—		
Cornwall	362,343	
Devonshire	601,374	
Somersetshire	463,483	
Gloucester (part of)	236,513	
Dorsetshire	195,537	
Wiltshire (part of)	197,419	
Hants (part of)	478,769	
Sussex (part of)	33,358	
		2,568,796
Eastern Sub-Commissioner :—		
Wiltshire (part of)	59,758	
Gloucester (part of)	42,863	
Oxfordshire part of)	176,835	
Northampton (part of)	8,305	
Berkshire	196,475	
Hants (part of)	65,915	
Sussex (part of)	384,098	
Surrey	1,091,635	
Kent	848,294	
Buckingham (part of)	111,231	
Hertford (part of)	159,591	
Middlesex	2,539,765	
Essex (part of)	450,284	
Suffolk (part of)	304,294	
Norfolk (part of)	347,564	
Bedford (part of)	32,017	
		6,818,924
Total under Southern Commissioner		9,387,720



Map of Districts Proposed by A. T. Atchison.

APPENDIX B.—(*Continued.*)

TABLE 3.—SUMMARY OF TABLES 1 AND 2.

	Area Sqre. Miles.	Population.	Mean Rain. (Range of Mean.)	No. of Watershed Basins.	Principal Water-bearing Formations, Surface and Subterranean.
			Inches.		
ommissioner of Northern Boards.					
Western Sub-Commissioner	7,966	4,089,621	25 to 75	44	Silurian, carboniferous, and New Red Sandstone.
Eastern Do.	8,605	3,547,838	25 to 50	24	Carboniferous, New Red, Oolite, and chalk.
Total	16,561	7,637,459		68	
ommissioner of Midland Boards.					
Western Sub-Commissioner	10,075	2,234,350	25 to 75	34	Silurian, Old Red Sandstone, carboniferous, and New Red.
Eastern Do.	10,876	3,452,737	25 to 50	14†	New Red, Oolite, lower greensand, chalk.
Total	20,951	5,687,087		48	
ommissioner of Southern Boards.					
Western Sub-Commissioner	9,181	2,568,796	25 to 75	70*	Devonian, carboniferous, New Red, Oolite, and chalk.
Eastern Do.	11,226	6,818,924	22 to 40	31†	Lower Wealden sands, lower greensand, chalk, tertiary.
Total	20,407	9,387,720		101	

* With "St. Ives," not numbered on Ordnance Map. † With part of No. LXXXVI.

ESSAY BY A. T. ATCHISON.

MOTTO.—"Water, water, everywhere,
But not a drop to drink!"[*]

The President and Council of the Society of Arts directed public attention, last year, to one of the most pressing and important wants of the day, when they inaugurated the Congress on National Water Supply. It is difficult or impossible to over-estimate the magnitude of the question under consideration; and, whilst the sewage difficulty, which has now for many years received great attention, is, doubtless, of vital importance, it must occupy only the position of a subsidiary element in the subject of National Water Supply.

In response to the request of the Council of the Society for suggestions founded on evidence already published, for the division of England and Wales into districts, with the object of securing a supply of pure water to the towns and villages in each district, the following outline of a scheme has been prepared.

All divisions, unless specially made for each purpose they have to serve, must necessarily be arbitrary, as is too apparent in the ancient boundaries of counties or parishes, or in the new boundaries proposed for local board districts or borough extensions.

It has been frequently laid down, as an inviolable maxim in the demarcation of districts for purposes of river conservancy and water supply, that the water-shed should be the boundary. This though the primary basis adopted, has not been arbitrarily adhered to. A careful examination of the distribution of the population was first made with the view of ascertaining what localities appeared, *prima facie*, in most need of relief.

It was at first attempted to indicate approximately the relative distribution of the population, by drawing circles whose areas were proportional to the number of inhabitants round each of the principal towns and cities, but it was soon found that if the scale of area to number was made sufficiently large to give any indication in the more sparsely populated districts, the effect became delusive in the denser parts, owing to the overlapping of the circles.

It was therefore decided—bearing in mind that the proposed scheme of dividing the country into hydrographical districts was necessarily of a large and comprehensive, rather than of a minute and detailed nature—that a map indicating the average density of population throughout an entire county would be sufficiently approximate for the purpose. With this view, the accompanying map has been prepared. Still further to simplify matters, the 54 counties in England and Wales (the sub-divisions of Yorkshire being treated as separate counties) have been divided into five different groups, in order of the average density of their population, and coloured with a red tint of depth corresponding to the density.

Table I. shows the area, population, increase per cent. in the last three decennial periods, and density of population in 1871, as represented by the number of persons per 100 acres. The watersheds, or boundaries of catchment basins, were then laid down on the map, from the map of river basins contained in the 6th Report of the Rivers Pollution Commission, and special attention was directed to those basins shown to be most densely populated. The hydrographical districts being thus provisionally laid down, the whole of the principal towns were then tabulated, with their population and geological formation, and all the available information sought respecting the source, quality, and quantity of their water supply. It need hardly be said that, with the exception of those places which furnished information on the subject to the Rivers Pollution Commission, and in answer to the inquiries of the Society of Arts last year, and a few others, very little material is to be found for forming a judgment of the nature of their supply. It was found that, in a great majority of towns, an adequate supply of good water was either in their possession, or within easy reach, but in a great number of these instances the danger or certainty of future pollution of the pure sources is at once apparent.

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[*] Two Essays were sent in with this motto.

There are, however, some large towns or groups of towns, which are so situated as to render it almost impossible for them to obtain a sufficient quantity of pure water within their own river basin. It is these towns that show the necessity of the legislation ultimately contemplated by this Congress. If a district finds itself unable to procure a good and adequate supply near home, it naturally casts its eyes abroad. Selecting some, as yet, unappropriated source, Parliamentary powers are sought, and perhaps obtained, in spite of opposition, and a catchment area allotted to a district at a distance, to the exclusion of one nearer. Thus it has happened, and doubtless will happen again, that an excellent source placed by nature within the grasp of the inhabitants in need of it, has, by their supineness, been allowed to pass into the hands of others. The great object, then, of dividing the country into districts, is to secure to those towns and villages the possession of the sources most favourably situated for their use at whatever time it seems good to them to take them, and at the same time to ensure that no community shall in future be cut off from all chance of a good supply, provided they take in good time the proper measures to preserve its purity.

All that is attempted in this paper is to give a preliminary sketch of the main outlines of these districts. It will readily be seen that if the districts are too large, almost all the evils necessitating their formation will recur, only perhaps on a smaller scale. Thus, for example, while London is prevented from taking the supply best adapted to Manchester and its neighbourhood, Leeds might still acquire that which should be reserved for Bradford. As already stated, these primary divisions were first tentatively made conterminous with the principal river basins, when it was found on examination that the population, with every allowance for prospective increase, had within their district an ample supply of unpolluted water, and that no neighbouring district was by the provisional boundary cut off from their only chances of an adequate supply in the future, then that boundary was decided on. When, however, it was found that the provisional boundary of a district did not enclose sources considered sufficient for future requirements, that boundary was abandoned, and the whole or parts of neighbouring districts included with it.

After due consideration of the facts obtainable, it is believed that the primary divisions shown on the map will, in the main, meet the requirements of the case, but in thus foreshadowing the direction in which steps should be taken, it must be borne in mind that a careful survey of the ground, and a more ample collection of statistics must cause much alteration in detail. It is foreseen that, before division of the country into primary districts is of much practical benefit to the inhabitants, that a further sub-division into sub-districts will be necessary; but before this can be accomplished with any certainty of success, the measures recommended in the resolution of last year's Congress must be adopted. A vast amount of detailed information, in the form of observations, reports, plans, and gaugings, exists in the hands of companies, corporations, engineers, and chemists, which has never yet been made public, and which might be rendered available. Mr. G. J. Symons, F.R.S., has for a great number of years devoted himself most indefatigably to the enrolment of an immense staff of rainfall observers, and to the tabulation and comparison of their returns. The British Association, through their Committee on Underground Waters, has done much valuable work in a parallel direction, while Messrs. Baldwin Latham and Lucas are pursuing investigations of an equally useful nature; but, unless we are contented to wait for a century at least, the attainment of the object in view must not be left to private enterprise. The appointment of a permanent Commission or department "to investigate and collect the facts connected with water supply in various districts throughout the United Kingdom, in order to facilitate the utilisation of the national sources of water supply for the country at large" is indispensable, and, further, to strengthen their hands, it should be enacted that every corporation, company, local board, or other body exercising powers conferred under Act of Parliament be compelled to furnish to the department a copy of every report, analysis, plan, section, gauging, or other observation received by them on the subject of water supply, drainage, or river conservancy.

The question of river conservancy, considered as bearing on the control of rivers, and which is at present before the Houses of Parliament, is intimately bound up with that of national water supply. It is of the greatest importance, then, that any legislation which is undertaken should pay due regard to both. The primary divisions will now be considered in detail.

THAMES DISTRICT.

This district has a present population of about 5,193,000. Rainfall varying from 24 to 34 inches per annum, and averaging about 26 inches. Geological formations, middle and lower oolite, chalk, lower greensand, and London clay. The water supply of London and its suburbs constituting a population within the Metropolitan

Police area of 3,885,641, in 1871, or, at the last decennial rate of increase, 4,463 816 in 1879, is by far the most important element of consideration in this district. To dissect and analyse the vast amount of evidence that has been collected on the present state of the metropolitan supplies, or to discuss the various proposals that have been for many years made for their improvement, would be quite beyond the scope of the present paper. It is no use shutting our eyes to the fact, that the present supply of Thames water delivered in London is largely contaminated by the washings from highly cultivated lands, the discharges from paper mills, tanneries, and other manufactories, in addition to the sewage of 900,000 persons, the bulk of which is but imperfectly cleansed before admission into the river.

A slight freshet, particularly in summer, serves at once the purpose of flushing the accumulated filth from the river, and enriching the product delivered to the consumer.

By the enlargement of subsiding reservoirs, and the exclusion of flood waters, accompanied by careful and efficient filtration, the character of the water can, doubtless, be rendered comparatively inoffensive; but the fact will still remain that the diluted washings and excreta of the human and animal inhabitants of the catchment basin above the intakes, are still drunk by those addicted to this beverage. The same remarks apply to the River Lee water, but with greater intensity from the larger proportion of its normal flow, which is abstracted for the London supply. The day cannot be far distant when the present supply will be abandoned; but whether an entirely new supply must be sought, or merely a pure supply for drinking and cooking purposes, need not be here discussed. The proposals for obtaining a supply of the highest excellence from North Wales or the Cumberland lakes are, doubtless, not only practicable, but not out of all proportion costly.

In considering the division of the country into hydrographical districts, with due regard to the density and rate of increase of the population, it appears at once unfair to allot either of the above catchments to the metropolis, and that such heroic measures are entirely unnecessary can be shown by an examination of the Thames basin.

It has been stated (Sixth Report Rivers Pollution Commission) that the chalk and upper greensand formations cover an area of 849 square miles within a 30 miles radius of London, 1597 square miles within 40 miles, and 2,150 square miles within that portion of the Thames basin lying within a 50 miles radius. Now, half an acre of catchment is sufficient for a supply of 30 gallons per diem per inch of available rainfall. Taking the available rainfall as 2½ inches, or less than the equivalent of the mean dry weather flow of the entire Thames basin (2·93 inches per annum), each acre of catchment will provide five persons with 30 gallons per head, and 2,150 square miles will suffice for the same supply per head to 5 × 2,150 × 640 = 6,881,000 persons. Although it might be unwise to calculate on a very much larger supply per acre than the amount here taken, experiments extending over a number of years have shown that this estimate is well within the mark. Of the purity of the water obtained from these sources there can be no question, and if the supply for domestic purposes be first treated by Dr. Clark's softening process, no exception can be taken to it on the score of hardness.

The Commissioners on Water Supply, discussing this source, observe, "moreover, as the water which penetrates into the reservoir (*i.e.* the subjacent chalk) raising the water line more or less above the level of the adjoining valleys, ultimately in greater part finds its way by springs into streams at the lower level of the district, any water drawn from the store, by artificial means, will most probably be at the expense of these streams. If this be true, it follows that any water obtained by tapping the chalk reservoirs that feed the River Lee or the Thames would, only *pro tanto*, diminish these streams, and would, therefore, be little or nothing gained to the general supply."

It is here maintained that this deduction of the Commissioners will not be borne out by fact, for the following reasons. That much water absorbed by the chalk on the south side of the basin finds its way direct into the tidal channel of the river, and might, therefore, be intercepted and rendered available by pumping.

That the absorptive capacity of the chalk and other porous formations would be increased by pumping from deep wells, the natural underground channels being cleared and enlarged thereby, the hydraulic inclination increased, and the drainage of the upper strata thus accelerated.

Another consideration, affecting the volume of the rivers laid under contribution for the supply of the metropolis, has been lost sight of by the Commissioners. An inspection of the diagrams, in the Sixth Report, showing the daily flow of the Thames, proves the truth of the recommendation of the Commissioners that "nothing less than 80 or 90 days' storage will render them (the Water Companies) independent of flood-water in autumn and winter." When the river, after long-continued floods, has resumed a fit condition for taking into the works, not only has it to meet the daily demand, but also to supply the much greater draught on its flow, for the replenishment in a few days of the whole of the nearly exhausted store. It may thus occur that at times a large proportion, or the whole even, of the dry weather flow is being abstracted by the works. Unless other sources are obtained, the growth of the metropolis, and the increased storage provided by the companies, will soon render this evil apparent. In pumping from deep wells for the supply of the metropolis, the loss to the river of that portion of the water only which is intercepted from the non-tidal part of the river will be felt, and the demand being spread uniformly over times of flood and drought, in place of being made, as in the previous case, only during the period of normal flow, will cause a much less serious diminution.

Thames Basin.

Abingdon.—Upper greensand; population, 5,809.

Aylesbury.—Upper oolite; population, 6,962.

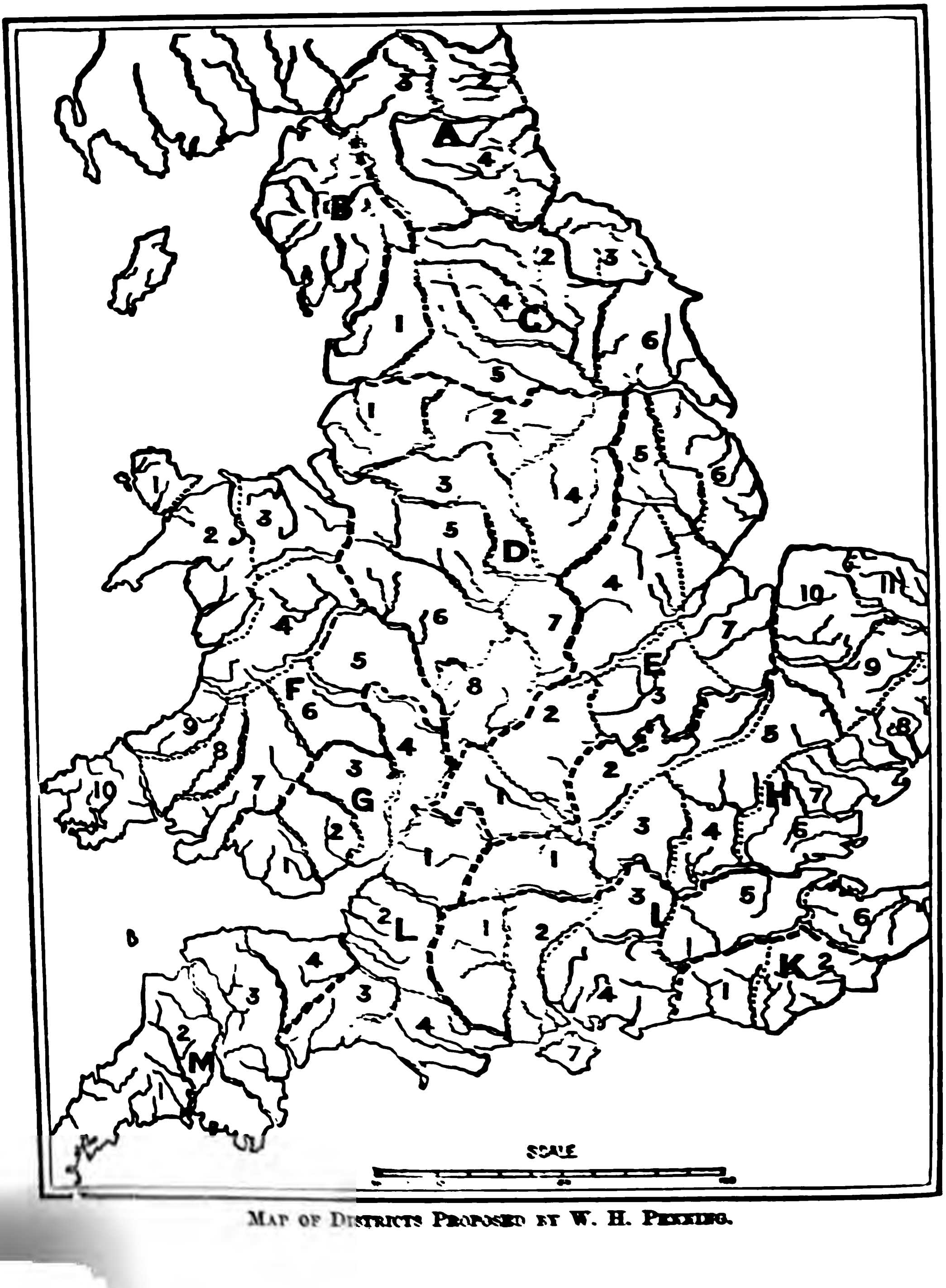
Banbury.—Lias; population, 11,726. From the Cherwell: much polluted by sewage and animal matter, and too hard for washing.

Basingstoke.—Chalk; population, 5,574. Well in chalk; 130,000 gallons pumped to reservoir daily; constant service, 40,000 gallons of which to 300 houses, 80,000 to 10 works and manufactories, also railway station. Supply bright, clear, and wholesome, but too hard for washing.

TABLE II.

	Area in Acres.	Population in 1871.	Increase per cent. in 10 years.			Persons per 100 acres, 1871.
			1841—1851.	1851—1861.	1861—1871.	
I. ENGLAND:—						
Westmoreland	500,906	65,010	3	4	7	13
Yorkshire, North Riding	1,361,664	293,278	5	14	20	21
Cumberland	970,161	220,253	10	5	7	22
Hereford	532,898	125,370	2	7	1	23
Rutland	94,889	22,073	8	—5	1	23
Lincoln	1,767,962	436,599	12	1	6	24
Huntingdon	229,515	63,708	10	0	—1	27
Salop	841,167	248,111	2	5	3	29
WALES:—						
Radnor	276,552	25,430	—3	3	0	9
Merioneth	385,291	46,598	—1	0	20	12
Brecon	460,158	59,901	11	0	—3	13
Montgomery	485,351	67,263	—3	—1	1	14
Cardigan	443,387	73,441	3	2	2	16
Carmarthen	606,172	115,710	4	1	4	19
Pembroke	393,682	91,998	7	2	—4	23
Anglesey	193,511	51,040	13	—5	—7	26
Denbigh	392,005	105,102	5	9	4	27
Carnarvon	369,482	106,121	8	9	11	29
II. ENGLAND:—						
Northumberland	1,290,312	386,646	14	13	13	30
Wiltshire	859,303	257,177	—1	—2	3	30
Dorset	627,265	195,537	5	2	4	31
Norfolk	1,356,173	438,656	7	—2	1	32
Cambridge	524,926	186,906	13	—5	6	35
Yorkshire, East Riding	750,828	268,466	13	9	22	35
Devon	1,655,161	601,374	6	3	3	36
Buckingham	467,009	175,879	5	3	5	37
Suffolk	949,825	348,869	7	0	4	37
Northampton	629,912	243,891	7	7	7	38
Oxford	470,095	177,975	4	0	4	38
Cornwall	869,878	362,343	4	4	—2	41
Berkshire	450,132	196,475	5	4	11	43
Essex	1,055,133	466,436	7	10	15	44
Somerset	1,049,815	463,483	2	0	4	44
Sussex	934,006	417,456	12	8	15	44
Bedford	295,509	146,257	15	9	8	49
Herts	391,141	192,226	7	4	11	49
WALES:—						
Flint	169,662	76,312	2	2	9	45
III. ENGLAND:—						
Leicester	511,719	269,311	7	3	13	53
Southampton	1,032,105	544,684	14	19	13	52
Monmouth	368,399	195,448	17	11	12	53
Derby	656,243	379,394	9	15	12	57
Nottingham	526,176	319,758	8	9	9	60
Gloucester	804,977	534,640	6	6	10	66
Worcester	472,453	338,837	11	11	10	72
Chester	705,493	561,201	15	11	11	79
Kent	1,004,984	848,294	12	19	16	84
WALES:—						
Glamorgan	547,070	397,859	35	37	25	72
IV. ENGLAND:—						
Durham	647,592	685,089	27	30	35	106
Yorkshire, West Riding	1,770,359	1,874,611	14	14	21	106
Warwick	566,458	634,189	18	18	13	112
Stafford	732,434	858,326	19	23	15	117
V.						
Surrey	483,178	1,091,635	17	22	31	225
Lancaster	1,207,926	2,819,495	22	20	16	233
Middlesex	181,317	2,539,765	20	17	15	1,401

NOTE.—Decrease of population is shown by a minus sign, thus —5



MAP OF DISTRICTS PROPOSED BY W. H. PENNING.

ESSAY BY W. H. PENNING, F.G.S.

Motto—"Nemo."

PRELIMINARY CONSIDERATIONS.

As all sources of water supply depend entirely upon physical conditions—the rainfall upon situation and elevation, the rivers upon physical features, and the springs upon geological characters—plans for division of the country should certainly be based upon its physical structure.

England and Wales fall naturally into three large, but unequal, sections, separated from each other by the great water-parting which divides the areas drained by rivers flowing towards the east, west, and south. These sections are divided by the main water-sheds into river-basins, and these are subdivided into smaller basins or valleys, each occupied by a tributary of the larger rivers. Such divisions are, of course, purely physical, although not in all cases well marked by physical boundaries, and the division of the country, for the purposes of water supply, into districts, each district consisting of some definite drainage area, would present a plan possessed of certain undoubted advantages. On the other hand, it would have its disadvantages, the two chief of which are, that the one-half of each district would be entirely cut off from the other by the river in its centre, and, any works proposed for a supply of water, wholly or in part by gravitation, must be at or near its margin. If such a plan were adopted, two sets of works, belonging to two adjoining districts, would be in close proximity, and would involve, in some cases, an expenditure double that which would be sufficient for the works in question. In the following suggestions, the object kept in view is to utilise the advantages offered by the structure of the country, avoiding, amongst others, the two chief disadvantages referred to, of taking the river basins as independent districts for the supply of water to the towns and villages within them.

The subject demands consideration under two headings:—1. Division of England and Wales into districts. 2. Mode of supply of pure water to the towns and villages in each district. It is treated as concisely as possible, consistent with making the suggestions clearly understood, and to the same end all details of areas, population, &c., have been given in tabular form in an appendix.

1.—DIVISION OF ENGLAND AND WALES INTO DISTRICTS.

It is suggested that England and Wales be permanently divided into twelve main sections, each one being separated from those adjoining by well marked physical features. The proposed plan of division is exactly the reverse of that of river basins, the lines of separation being not the water-sheds, but the rivers. All the large and some of the smaller rivers, therefore, form the boundaries of these sections, which thus have low and comparatively level ground at their margin. They are traversed throughout a good part of their length by a central elevated line of water-shed, or, in some instances, by the main water-parting of the country. The surface waters of each section thus flow in two directions from the central lines, one portion going to the river of one basin, the other into that of the adjoining basin, or directly down to the sea. As rivers follow a definite course, the boundary of each section thus circumscribed is (with trifling exceptions) very clear, and in many respects is to be preferred to an arbitrary line, or to an irregular margin, such as is presented by a winding and frequently indistinct line of water-shed, which always varies with the contour of the higher and more broken tracts of country.

The accompanying map shows the proposed sections, lettered A to M respectively, their boundaries being described in Table I, Appendix, page 40.

Rivers frequently follow, for a considerable distance, a course corresponding, or nearly so, with geological lines of division; as examples may be mentioned the Trent and the Severn, near the junction of the Triassic and Liassic formations. The main lines of water-shed, on the other hand, frequently coincide for great distances, with geological escarpments, as the Chiltern Hills formed by that of the Chalk, and the Cotswolds by that of the Lower Oolites. Therefore, the sections having rivers for their boundaries, and main water-sheds for their longer axes, will include larger areas of similar geological structure than the river basins do, which, as a rule, have widely differing rocks on opposite sides, the Thames being the only noteworthy exception. As an example, Section H. may be mentioned, which is mainly bounded by the Thames and Ouse rivers, or by main branches from those rivers, and is traversed throughout its entire length, from Marlborough in Wiltshire to the north coast of Norfolk, by the chalk escarpment; and as the water supply of any area is directly dependent upon its geological phenomena, the water-bearing conditions, as well as those of a physical character, are more or less alike throughout each section.

The map, No. 3 (sent in with the paper), represents approximately the geological structure of the country, being divided, not strictly into geological formations, but with more regard to water-bearing characteristics. The colours, four in number, indicate the different classes into which the rocks may be conveniently divided:—

w. Pink.—Reliable water-bearing formations.

x. Neutral tint.—Uncertain rocks, which yield an abundance of water in some districts, and none whatever in others.

y. Blue.—Impervious clays, non-water-bearing, but generally with water-bearing beds beneath, and sometimes intercalated with them.

z. Grey.—Igneous, crystalline, and similar rocks which yield no water, and have no pervious beds beneath.

The sections, A to M, are proposed to be further divided into sixty-eight districts, upon a plan exactly similar to that suggested for the primary division. Each district is bounded by main tributaries of the rivers, and is traversed by one or more of the chief local water-sheds. The streams which flow into the main tributaries enclose still smaller areas, traversed by minor water-sheds at a relatively lower level, and such areas can, if it be found necessary or desirable, be formed into sub-districts upon exactly the same plan of sub-division. But the proposed districts only are shown on the map, any further division necessarily depending upon the strictly local geological structure and relative elevation.

The division of the sections, A to M, into districts is shown on map, the districts being figured according to the number in each section. The dotted lines indicate generally the main lines of water-shed and their chief branches only; the secondary and subordinate branch lines of water-shed being too numerous to be shown, without actual and detailed examination of the country for that purpose.

Particulars are given in Table II, pages 40-43, in Appendix, of the size of each district, its population and average rainfall, in approximate numbers, London only being omitted. The London water supply is a matter demanding special investigation, and is beyond the "suggestions for supply to towns and villages." It may, however, be added that there is no very evident reason why the methods proposed should not, on a more detailed and extensive scale, be equally applicable to the supply of the metropolis.

Each section to be governed by a Board, consisting of representatives from each district within it, who shall have control over all matters of construction and expenditure by which the interests of the section, as a whole, are affected. For instance, by the order or sanction of this Board, the works of two or more districts may be wholly or partially united, where desirable, for the purpose of equalising supply; the cost of works in one district for the benefit of another may be fairly apportioned between them, and the reserve of water in all or any of them may be increased or diminished. Each district being complete in itself, is, as regards local matters, to be under separate and local management, subservient, however, as suggested above, to the central authority of its own section.

The chief points in favour of this plan for division into districts may be briefly summarised, as:—Definite physical boundaries; high ground in a central position; low ground at the margin; similarity of geological (therefore of water-bearing) structure. Each section and each district is accessible throughout, is independent of the others, and is capable of subdivision on the same plan, &c., &c. For distribution of water it will also be found convenient, as will be shown in the sequel.

The information conveyed by the maps, with the details given in the Appendix, although compiled from reliable sources, is intended to be approximate only, but it is sufficiently correct as a foundation for these suggestions. The accurate working out of details, physical and geological, upon which alone a final division of the country can be made, is a task far beyond the power of one individual during the time allowed. It must be undertaken systematically, if ever, by a staff of geological surveyors, well acquainted with the phenomena of water supply, and might well form a branch of our National Geological Survey. The maps already published by that department would yield much assistance, and if supplemented by another examination of certain districts, from this special point of view, would leave little to be desired. Where the survey is still in progress, the water-bearing characters of the rocks might receive additional attention, and approximate heights of the water-sheds be collected at the same time. It is known that, in addition to their published works, the Government geologists have at command numerous notes, sections, and other valuable data, bearing upon this important question, and which would doubtless be readily forthcoming if required. The consequent works must be devised by engineers separately for each district, and founded upon the information thus obtained, considered in relation to their "wants and varying specialities."

2.—Mode of Supply of Pure Water to the Towns and Villages in each District.

The physical conditions are more or less different in each district; therefore, the sources and quantity of available water also vary, being wholly governed by those conditions. The physical features have, in addition, a direct and important bearing upon the methods of distributing the supply, in the quantity and manner best suited to the requirements of each locality. The two subjects, thus affected by the same influence, are intimately blended, both forming an essential part of the mode of supply; but they will, as far as practicable, be kept distinct and treated under two sub-headings:—

a. Source of supply, and *b.* Mode of distribution.

a.—Sources of Supply.

The phenomena of springs are now so well understood that a description of them need not be given here, but a few remarks may be made upon one or two points, in support of the suggestions which follow, and which are founded upon them.

It may be taken as a general rule that ridges and escarpments consist, wholly or in part, of water-bearing beds, such as limestone, chalk, or sandstone, and that the softer clays, being more readily denuded, occupy the lower grounds.

Strata generally dip towards and pass under the higher grounds; it is rarely they occur otherwise, and they are not often found quite horizontal. This is owing to the fact that the lie of the strata has, in a great measure, given to the ground its present form; in other words, anticlinals are more easily denuded than synclinals, the latter remaining whilst the former have yielded to denudation.

Case 1. Any set of pervious strata which occurs at the surface, as at *a a* in the diagram, will (as a rule) form a trough, and be found below the ridge, *R*, at a greater depth than is due to the difference in height of *a* and R. Water collected by these pervious beds upon their outcrop, *a a*, will rise in a boring made at R, through the impervious beds, *b b*, to a height corresponding (or nearly so) with that of their outcrop. Surface gravels are no exception to this general rule, and often occur in long hollows on elevated ridges, throwing out intermittent springs at the lowest points along their margin, *d d*. It is owing to the more rapid erosion of anticlinals that rivers and streams so frequently follow, at a greater or less distance, lines of geological boundary, a fact previously referred to, and of which advantage is taken in the proposed plan of division.

Case 2. The same pervious beds, *a a*, when dipping into the face of an escarpment, E, probably decrease in dip at a short distance beneath it, or even become horizontal, and they would be reached by a boring made on the top of the escarpment, E, at a depth not much below that of their outcrop, the water from them rising in the bore to an extent coinciding with the difference, whatever it may be.

Case 3. Where pervious beds, *c c*, in considerable thickness, overlie impervious beds, *b b*, and form an escarpment, E, or a ridge, R, the water-level within them rises beneath the higher grounds until the forces of hydrostatic pressure and frictional resistance are in equilibrium. Water will, therefore, be frequently found in borings commenced on a ridge, R, or escarpment, E, at a height very considerably above that of the lowest points of their nearest outcrop, *b b*, where the surplus water flows forth as perennial springs.

As strata dip towards the higher grounds, the water collected on slopes and in valleys flows underground in the same direction. Therefore, in river basins, where bounded by escarpments, the water collected in one basin flows towards and beneath another, but in districts as proposed, it is chiefly (although not invariably) available within its own area.

Water collected upon surface gravels, *d*, or other pervious beds similarly situated, and held up within them by impervious beds beneath, are available on ridges and escarpments by wells of moderate depth. The springs at the margin of such beds may also be utilised at a high level, and the water in nearly all such cases would be pure, as towns and villages are rarely found in these situations.

In the thick permeable beds, *c*, water is found at a moderate depth beneath the higher grounds, and in the pervious beds, *a*, at a greater depth, but in the latter case it will be nearer to the surface along the courses of lateral valleys.

The conditions illustrated in the diagram, of course, vary greatly, but the principle remains the same, and is utilised in the proposed methods of supply, as hereafter described.

An important phenomenon connected with questions of water supply here demands brief consideration. Strata that now throw out springs, or yield water when pierced, would, if occurring at a different level, or if inclined at a suitable angle, become the means of draining water away from other parts than that in which their waters are now collected. This follows as a matter of course, for the conditions would merely be reversed, and the water would pass through the beds in another direction, the springs of one locality being, in fact, but the natural drainage of another. Slight consideration renders evident the truth of the proposition that a well, capable of yielding a given quantity of water, is equally capable of getting rid of the same quantity by absorption. Water is not elastic, and when it bursts up from a penetrated rock, it does so not from the force of expansion, but from that of hydrostatic pressure. And it rises to a certain height only, that of its present normal water-level; when this is attained in the well, and there is no outlet below that level, it rises no further. As it is pumped out, more water takes its place (if the pumping does not exceed the yield of the spring), but it never stands higher or falls lower than a definite point. Therefore, if water be put into the well, thus tending to increase the height above that point, the action is reversed, and the water so put in sinks down to the water-level at once, if its quantity does not exceed the yield of the spring. The rapidity with which water flows into a well depends directly upon the permeability of the strata through which it passes, and upon the same condition depends also the rapidity with which it can flow away from it; consequently, the spring is capable of yielding and of absorbing the same quantity of water.

Absorption wells may be employed with safety and advantage in getting rid of an excess of water from certain localities, in conveying it to others, and generally, on a give-and-take principle, in connection with water works, wells, and reservoirs.

It is beyond question that the total annual rainfall of England and Wales is, in every part, far in excess (in the ratio of about ten to one even in most unfavourable years) of what is actually required for a supply to the towns and villages, and is sufficient to keep the springs full from which its greater part is proposed to be drawn. But where no springs exist, either near the surface or at a great depth, the rain water or some other source must be utilised, if the vast cost of conveying water from one district to another at a great distance is to be avoided. The districts thus without, or comparatively bare of springs, are, however, those upon the older crystalline, metamorphic, and igneous rocks, from and beneath which but little, if any, water can be obtained. But it is on those non-water-bearing rocks that the "upland surface waters" are in their greatest purity, and if a sufficient quantity of that water can be stored in such districts to last over the dry periods, no better supply would be needed. These districts, owing to their situation, have a very large rainfall, unequally distributed throughout the year, the excessive fall of some months running rapidly away to the sea, leaving several dry months during which no sufficient natural source is available.

Generally speaking, such districts are thinly inhabited, the most populous areas being those upon rocks that are water-bearing; the supply of water from them having, doubtless, been one of the chief causes of the local growth of manufactures upon them, and the spread over their surface of a large population. A store of water to supply the districts in question might, therefore, be comparatively small; and in any district where it could not well be stored in sufficient quantity, that district will certainly be found, in other respects also, unsuited to the maintenance of a large community. In the rare cases where a supply can be had neither from springs nor by storage of rain-water, the streams and other present sources of supply must be relied on, possibly extended and certainly improved in regard to filtering arrangements.

In these suggestions, rivers and streams are not proposed to be utilised as sources of supply, except in the rare instances just mentioned, as their waters, being all more or less polluted, can only be rendered fit for drinking purposes (and this not in all cases), by an expensive process of filtration. But the head-waters of many rivers, where they exist as streams at a high level, and above the sources of contamination, may be safely used as an auxiliary supply of good water in such a position that it can be economically employed.

b.—MODE OF DISTRIBUTION.

The suggestions under this heading are of necessity brief, and of a very general character, details being purposely avoided. The latter can be of value only after a complete survey of each district, and when designed by an engineer, after a thorough consideration of all the ascertained facts of physical feature, geological structure, possible water supply, existing works, and special requirements. The general plan of each proposed method is described, but it is to be understood that these may be modified according to the nature of each district, and are not to be applied alike to all. In some districts all the modes may be adopted at a considerable saving of cost, while attaining the same results as if one plan only were adhered to throughout. Indeed, it is scarcely possible for it to be otherwise, as any one plan, applied in its integrity over a large and varied area, must be costly, and may or may not be effectual.

It is suggested that main lines of reservoirs, at a distance apart varying with the circumstances, be established along the chief water-shed, or water-sheds, of each district, the number and size of the reservoirs to be governed by the nature of the source whence each will be supplied. The available sources of pure water are of three kinds, and have been shown to be—

1. Shallow wells and surface springs.
2. Borings to deep-seated springs.
3. Surface collection of rain-water.

1. Drift gravels and other pervious strata occupy the higher grounds, and yield water at a moderate depth. Sites are to be selected upon, or rather near to, such beds where they occur on the main water-sheds, whether as ridges or escarpments. The reservoirs are there to be made to a depth below the lowest part of the pervious beds; a channel then cut longitudinally through the beds will tap their springs, which can be led directly into the reservoirs. Or the supply may, in some cases, be taken by pumping from shallow wells sunk in the beds, or by leading water into the reservoirs from the overflowing springs on their margin.

2. Reservoirs thus situated on the higher grounds are in an exceptionally good position for obtaining a supply of water from deep-seated springs, and borings there made down to each of the water-bearing formations beneath, would almost invariably ensure a good supply.

3. The reservoirs are, however, not always to be made on quite the highest points of the water-shed line; they may with advantage be situated, in cases where no surface springs exist, considerably to one side of it, thus being below its highest level. In this case, where there are no pervious surface deposits, all the rainfall on the ground above them can be readily collected as an auxiliary supply to that derived from the deep-seated sources. Where there are neither deep nor surface springs, reservoirs of the main line may be at even a still lower level, on each side of the water-shed alternately, thus to collect rain-water from a larger area, generally of hard clean rocks, no supply, in such cases, being needed above them.

The main line reservoirs, when at the same level, and if not separated by too great an interval, are to be connected throughout the district by lines of pipes or open channels. When at different levels, they are still to be connected in the same way, but must then have intervening weirs and sluice-gates, or other appliances for regulating the flow from the higher to the lower reservoirs. When some of the reservoirs are very far apart from the others, those only in the same neighbourhood are to be connected with each other, thus forming two or more disconnected main lines in each district.

As the head waters of the rivers, rising from the higher grounds, flow towards each other to form united streams, branches from the main water-sheds run out towards the points of convergence. The more important of these main branches are to be occupied by reservoirs connected with each other and, if the conditions are favourable, also with the main lines, and supplied wholly or partly, as the case may be, by wells or by surface collections.

Similar lines of reservoirs to those on the water-sheds are to be formed on the flanks of the central elevation of each district, all those on the same side to be on, or about on, a level with each other. They will thus follow contour lines, touching the streams near their sources, and getting gradually away from them further down the valley. There may be one, two, or more of these secondary lines in each district according to the physical conditions, and the required supply, but there will be no subordinate branches. The diagram below shows generally the position of the main and secondary lines of reservoirs as suggested.

The reservoirs on the secondary lines will be supplied by borings, when the conditions are especially favourable, by spring-heads and local surface springs (when pure), and by the surplus water from the main lines, but only in very exceptional cases are they to be filled by surface collection, and then no lines but those at the higher levels. As a rule, all are to be connected by pipes or open channels following the contours, but breaks may be made in the continuity of the connection, or even of levels, to suit the varying circumstances.

Reservoirs for storing rain-water in the barren upland districts can be well and cheaply made in such situations, by throwing strong dams across the smaller valleys (in colonial fashion). These valleys are usually steep-sided, and thus would form small, deep lakes, which for many months might retain, in good condition, large bodies of water, with a comparatively small surface exposed to evaporation.

Upon, or rather just above, the lowest ground in each district, a continuous line, partly of open and partly of covered aqueducts, to be formed at descending levels, always sufficiently above and distant from the main stream, to supply the towns and villages situated near to, and about on a level with, the boundary. The aqueducts are to be continuous across the district, with weirs or sluice-gates at the changes of level; waste weirs are also to be provided at intervals, with channels to take the overflow into the stream or river. The water in the aqueducts is to be derived chiefly from the overflow of the main sources of supply on the higher grounds, supplemented by borings to deep-seated springs, especially to those which are known to overflow, and thus require no pumping.

The design and construction of the reservoirs, aqueducts, and works generally, are pure engineering matters, not to be entered on here; but a few brief remarks may be made upon the channels of connection, the mode of collecting surface waters, and underground distribution. It is suggested that, for economical reasons, the channels may be open at the top on the higher lands, where safe from chance of pollution. This may, in some cases, involve the cost of fencing, but this addition would probably be much more than balanced by the difference between that of open channels and of iron pipes. In some cases stone-ware pipes may be used cheaply and with advantage. Iron pipes will sometimes become a necessity, where low ground intervenes between two reservoirs that are to be connected, but in many cases level ground may be selected round the end of such depression, along which open channels may be constructed.

In all cases where these open channels are employed, they should be filled to the depth of a few inches with pebbles, or other uniformly coarse material, to prevent the growth of plants, and to promote the deposition of any suspended matter.

The rain-water would be collected, where necessary, in cross gutters or open ditches, intercepted by channels, following the contour lines; these would deliver the water first into a series of settling tanks (except in the barren upland districts), whence it would pass into the reservoirs which, in all cases, should be of sufficient depth to store a good portion of the storm waters.

The phenomena of absorption wells may be turned to account, in many instances, for increasing the yield of springs in one locality at the expense of those in another, where the supply is much in excess of what is required. There are many places in which the springs yield an almost unlimited quantity of water, which could be diverted into borings made down to another water-bearing formation. Each one of these borings would absorb as much as it would yield, and this absorbed water must, of necessity, go to feed other springs in the same formation, and which could be utilised elsewhere, sometimes within the same district, sometimes in those adjoining. In the latter case, the cost of making the absorption wells should be borne by the district thus benefited. In Table II absorption wells are mentioned in some of the districts where they may be adopted with advantage; but not by any means in all, as the existence of conditions favourable to their use must be (in all cases) determined by examination.

Water intended for absorption to remain awhile in the settling tank, or reservoir, to deposit its suspended matter, passing thence into the pipe leading to the bore-hole and standing up several feet above the floor of the tank, so as to prevent the entrance of sand and other material, by which the bore might be choked.

All overflow and surplus waters, from any source whatever, may thus be absorbed, so long as the streams are sufficiently full; but, when the streams are low, or falling, all surplus water must be allowed to pass into them by the overflow channels provided. Frequently, pervious beds outcrop along the flanks of hills and escarpments as at *a* in the diagram, and at a lower level in lateral valleys, when they can be used in a similar manner. By a simple process of heading the water back upon selected parts of their surface, it can be rapidly absorbed, and made to pass in to feed the springs beneath the higher ground.

CONCLUDING REMARKS.

An endeavour is made in these suggestions to effect, in almost every district, a combination, based upon the varying peculiarities of physical feature and geological structure, of two or more of the methods described in general terms; and to ensure by these means a reliable supply of wholesome water to the towns and villages, at the smallest possible cost consistent with that result, and with the establishment of works of a permanent character.

It will have been seen that the suggestions are founded upon the assumption that the largest supply of the purest water is to be obtained upon and beneath the highest grounds, and it is confidently believed that in a great majority of cases, a supply ample for the wants of a whole district may be derived from and beneath the water-bearing beds which occur in greatest number and most favourable circumstances beneath its watershed. Where water is known to occur in abundance at lower levels it will, of course, be utilised also to reduce the cost of the works elsewhere. It is, therefore, proposed to establish the more important of the requisite works, reservoirs, pumping stations, &c., upon the main water-sheds of each district, the reservoirs being connected, and subordinate pumping stations at lower levels, when they may be found necessary or desirable. The main pumps to be constantly at work, to keep the connected reservoirs full to over-flowing, the overflow (which, however, need not be large) to be directed into the secondary reservoirs below or their connecting channels, which in turn will flow over into those (if any) at still lower levels, and those again into the low level aqueduct, whence it passes into the river.

By this plan of connecting the reservoirs, the supply will be equalised over a large area, and there will be a constant circulation of the water beyond that caused by the actual consumption; but the additional water for this purpose need not be obtained at the expense of the streams. It will come chiefly from deep wells, and storm-water stored at high levels, and as the overflow can, where necessary, be directed into the streams at various points along their course, it will more than compensate for what may be, in some cases, taken from them at their source. When the reservoirs and channels are once full, the quantity required will be only equal to that of the actual consumption, *plus* the small per-centage for the proposed method of circulation. This additional water, if found necessary for circulation beyond what is kept up by consumption, may be utilised as a motive power to aid in the pumping.

There will be no necessity for a large reserve of water, beyond the requirements of any area, such as must always be provided where works are independent of each other, for every reservoir acts as a reserve to the others, and each may be proportionately smaller, at a saving of cost without decrease of efficiency.

The main reservoirs being on the highest ground, all towns and villages can be supplied with water by gravitation. This is an important consideration from an economical point of view; for, admitting that the work, as a whole, involves a great outlay, it must still be far below that which would be required even for each town (to say nothing of villages) to provide pumping-stations and water-works of its own, in many of which water-towers and costly machinery would form necessary parts of the undertaking.

Each town and village would have a constant supply, taken by mains from the nearest reservoir or aqueduct at the proper elevation, the cost of such mains and local works being borne by the town and village, while that of the general works —pumping-stations, reservoirs, aqueducts, and channels—would be equally or otherwise fairly distributed over the entire district.

In Table II, pages 40-43 in Appendix, particulars of each district are given, concerning its area, population, rainfall, geological structure, the water-bearing characters of its rocks, and (in general terms) the mode of supply to each based upon its physical conditions.

It may be added that a scheme of this kind could be carried out by degrees; if adopted for a small district, and there thoroughly tested, it might be gradually extended to other districts if the experiments were successful. All existing works might be utilised, dispensing with any polluted or doubted source of supply, and adopting those that are sketched out rather than described in these suggestions.

APPENDIX.

TABLE I.—Sections—Geology and Boundaries.

Section A.	On Carboniferous rocks.	N., Scotland; W., River Eden; E., North Sea; S., River Tees.
,, B.	On Silurian rocks (Lake District).	N., Solway Firth; W., Irish Sea; E., River Eden; S., River Kent.
,, C.	On Carboniferous, Trias, Lias, Oolites, and Chalk.	N., River Tees; W., River Kent; E., North Sea; S., Rivers Ayr and Humber.
,, D.	On Carboniferous and Trias.	N., Rivers Ayr and Humber; W., Rivers Dee and Severn; E., River Trent; S., River Avon.
,, E.	On Lias, lower Oolites and Oxford clay, some Chalk, and the Fenland.	N., River Humber; W., Rivers Dee and Avon; E., River Ouse and North Sea; S., Rivers Ouse and Thames.
,, F.	On Silurian.	N. and W., Irish Sea; E., Rivers Dee and Severn; S., Rivers Treme, Wye, and Teame, and the Bristol Channel.
,, G.	On Old Red and Carboniferous.	N., Rivers Treme, Wye, and Teame; W., Bristol Channel; E. and S., River Severn.
,, H.	Cretaceous and Tertiaries.	N, River Ouse; E, North Sea; S, Rivers Kennet and Thames.
,, I.	On Chalk and Tertiaries.	N., Rivers Thames and Kennet; W., Rivers Stour and Frome; E., English Channel; S., English Channel and River Medway.
,, K.	On Wealden, Gault, and Upper Greensand.	N., River Medway; W., River Arun; E. and S., English Channel.
,, L.	Continuation of Section E.	N., River Severn; W., Rivers Culm, Tene, and Ivel; E., Rivers Stour and Frome; S., English Channel.
,, M.	Similar to Section G.	N., Bristol Channel; W., Atlantic Ocean; E., Rivers Culm, Tene, and Ivel; S., English Channel.

TABLE II.—Districts.

	Area in acres.*	Population.*	Average Rainfall in inches.†	Geological Formations.‡	Water-bearing or otherwise.‡	Mode of Supply; described generally in the "Suggestions."
A^1	430,000	129,000	33	Carboniferous ... Igneous rocks ...	Uncertain. Non-water-bearing.	Two central disconnected main and branch lines of reservoirs, and secondary branch lines at lower levels; supplied partly by wells and partly by surface collection.
A^2	430,000	129,000	35	Carboniferous ... Millstone grit ...	Uncertain. ,,	Main line and two branches on W. side, with branch lines at lower levels; partly by wells and partly by surface collection.
A^3	543,000	140,000	43	Carboniferous ... Millstone grit ...	Uncertain. ,,	Two central disconnected main and two branch lines, with secondary branch lines; partly by surface collection.
A^4	1,070,000	766,000	32	Bunter ... ... Carboniferous ... Millstone grit ..	Water-bearing. Uncertain. ,,	Three connected main lines, with secondary branches; chiefly by surface collection; the S.E. corner, by wells in bunter.

* "Local Government Directory."

† Each inch of rainfall represents 100 tons of water per acre. Compiled from report of Rivers Pollution Commission.

‡ Report of Rivers Pollution Commission.

TABLE II.—(*Continued.*)

	Area in acres.*	Population.*	Average Rainfall in inches.†	Geological Formations.‡	Water-bearing or otherwise.‡	Mode of Supply; described generally in the "Suggestions."
B	1,165,000	495,000	63	Silurian Carboniferous Bunter (small area only).	Non-water-bearing. Uncertain. Water-bearing.	Radiating main lines of reservoirs, with secondary branches; by surface collection. The extreme N. by auxiliary wells in bunter.
C^1	663,000	920,500	50	Silurian Millstone grit Bunter	Non-wate-rbearing. Uncertain. Water-bearing.	Central main lines, and secondary branches; by surface collection, and by wells in bunter.
C^2	490,000	365,000	32	Millstone grit Bunter Keuper Lias Oxford clay Lower Oolites	Uncertain. Water-bearing. Uncertain. Non-water-bearing. ,, Uncertain.	Two disconnected main lines, and secondary branches; chiefly by wells in and down to the bunter sandstone, and by surface collection. (Absorption well in bunter, for surplus surface water from the millstone grit.)
C^3	446,000	346,000	28	Keuper Lias Oxford clay Lower Oolites	Uncertain. Non-water-bearing. ,, Uncertain.	Two disconnected main lines and secondary branches; chiefly by wells in lower Oolite.
C^4	441,000	343,000	36	Millstone grit Magnesian limestone Bunter	Uncertain. ,, Water-bearing.	Two disconnected main lines, and secondary branches; chiefly by surface collection; on the E. by wells in bunter. (Absorption well.)
C^5	550,000	555,000	50	Millstone grit Carboniferous Bunter	Uncertain. ,, Water-bearing.	Two disconnected main and two branch lines, and secondary branches; by surface collection; auxiliary wells on the E. in the bunter. (Absorption well between this district and D^2.)
C^6	470,000	380,000	28	Bunter Keuper Neocomian Lias Chalk Drift	Water-bearing. Uncertain. ,, Non-water-bearing. Water-bearing. ,,	Two disconnected main and one branch lines, and secondary branches; wells chiefly in chalk.
D^1	525,000	1,230,000	43	Millstone grit Carboniferous Bunter	Uncertain. ,, Water-bearing.	One main and one branch line, and secondary branches; by wells and surface collection; auxiliary wells on S. and W. in bunter.
D^2	631,000	761,000	32	Millstone grit Carboniferous Magnesian limestone Bunter	Uncertain. ,, ,, Water-bearing.	One main and two branch lines, and secondary branches; chiefly by surface collection; auxiliary wells on E. in bunter (Absorption well between this district and C^5.)
D^3	637,000	445,000	36	Millstone grit Carboniferous Bunter Keuper	Uncertain. ,, Water-bearing. Uncertain.	One main and one branch line, and secondary branches; partly by wells, and partly by surface collection; auxiliary wells in bunter, on W.
D^4	894,000	433,000	27	Magnesian limestone Carboniferous Bunter Keuper	Uncertain. ,, Water-bearing. Uncertain.	One main and one branch line, and secondary branches; by wells chiefly in and down to bunter; by surface collection on the W. (Absorption well.)
D^5	720,000	650,000	33	Carboniferous Bunter Keuper	Uncertain. Water-bearing. Uncertain.	Two disconnected main lines, with three branches and secondary branches; chiefly by wells in and down to bunter.
D^6	769,000	473,000	32	Carboniferous Bunter Keuper	Uncertain. Water-bearing. Uncertain.	Main lines on N.E., with three branches and secondary branches; chiefly by wells in and down to bunter.
D^7	296,500	206,000	28	Keuper	,,	Main line and secondary branches; chiefly by surface collection.
D^8	690,000	632,500	38	Bunter Keuper	Water-bearing. Uncertain.	Main lines with one branch and secondary branches; chiefly by surface collection, auxiliary wells on N.W. in bunter.
E^1	477,000	258,500	35	Lias Oxford clay Lower Oolites	Non-water-bearing. ,, Uncertain.	Two connected main lines, with secondary branches; partly by wells in and down to lower Oolite, and partly by surface collection.
E^2	417,500	313,500	30	Lias Lower Oolites	Non-water-bearing. Uncertain.	By main lines, with two branches, and secondary branches; by wells in lower Oolite, and partly by surface collection.
E^3	674,000	270,000	25	Lias Oxford clay Lower Oolites	Non-water-bearing. ,, Uncertain.	Two disconnected main lines, and secondary branches; by wells in lower Oolite, and partly by surface collection.
E^4	827,000	468,000	25	Keuper Lias Lower Oolites	Uncertain. Non-water-bearing. Uncertain.	Two connected main lines, and secondary branches; by wells in lower Oolite, and partly by surface collection.
E^5	500,000	125,000	25	Neocomian Lias Oxford clay Lower Oolites	Uncertain. Non-water-bearing. ,, Uncertain.	Two connected main lines, and secondary branches; by wells in lower Oolite, and partly by surface collection.
E^6	678,000	160,000	23	Neocomian Chalk Drift	Uncertain. Water-bearing. ,,	Main line, with four branches, and secondary branches; by wells chiefly in and down to chalk.
E^7	590,000	168,000	20	Oxford clay and alluvium (forming the Fen land).	Non-water-bearing	Extension and improvement of the existing mode of supply.
F^1	123,000	85,000	55	Silurian	Non-water bearing.	Main line, and secondary branches; by surface collection.
F^2	688,000	155,000	60	Silurian	Non-water-bearing.	Three disconnected main lines with secondary branches; by surface collection.
F^3	472,000	152,500	35	Silurian Carboniferous Bunter	Non-water-bearing Uncertain Water-bearing.	Two disconnected main lines with secondary branches; chiefly by surface collection.
F^4	829,000	144,500	54	Silurian	Non-water-bearing	Main lines with two branches, and secondary branches; by surface collection.

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* "Local Government Directory."

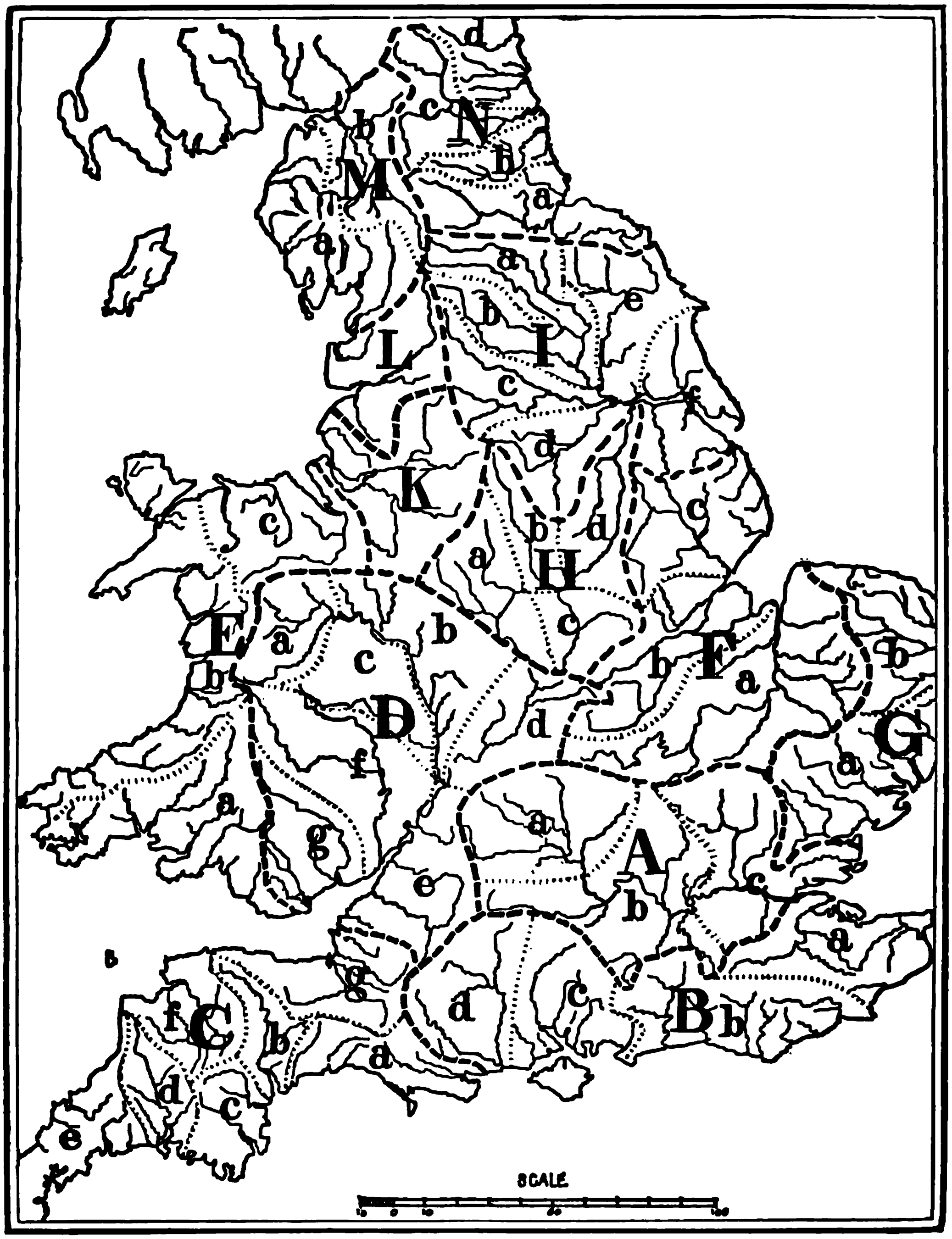
† Each inch of rainfall represents 100 tons of water per acre. Compiled from report of Rivers Pollution Commission.

‡ Report of Rivers Pollution Commission.

TABLE II.—(*Continued.*)

	Area in acres.*	Population.*	Average Rainfall in inches.†	Geological Formations.‡	Water-bearing or otherwise.‡	Mode of Supply; described generally in the "Suggestions."
F^5	628,000	290,500	33	Silurian ... ... Old red ... ... Keuper	Uncertain. „ „	Two connected main lines, and secondary branches; by surface collection.
F^6	380,000	52,000	43	Silurian ... ... Old red	Non-water-bearing Uncertain	Main line and secondary branches; by surface collection, and wells in old red sandstone.
F^7	636,000	178,000	60	Silurian ... ... Old red ... ... Carboniferous ...	Non-water-bearing Uncertain. „	Two connected main lines with one branch, and secondary branches; by surface collection, and wells in carboniferous and old red sandstone.
F^8	420,000	79,000	65	Silurian	Non-water-bearing	Main line and secondary branches; by surface collection.
F^9	240,000	40,000	45	Silurian	Non-water-bearing.	Main line and secondary branches; by surface collection.
F^{10}	369,000	86,000	46	Carboniferous ...	Uncertain.	Main line, with two branches, and secondary branches; by surface collection.
G^1	405,000	380,000	45	Carboniferous ...	Uncertain.	Two connected main lines, and secondary branches; by wells in carboniferous, and partly by surface collection.
G^2	373,500	199,500	45	Old red ... ... Carboniferous ...	Uncertain. Uncertain.	Two connected main lines, and secondary branches; by wells in carboniferous and old red sandstone. &c.
G^3	400,500	150,500	38	Old red	Uncertain.	Two disconnected main lines, and secondary branches; by wells in old red sandstone, and partly by surface collection.
G^4	485,000	241,000	28	Old red ... ... Keuper	Uncertain. „	Two disconnected main lines, and secondary branches; by wells in old red sandstone, and partly by surface collection.
H^1	594,000	224,000	30	Oxford clay ... Neocomian... ... Chalk	Non-water-bearing Uncertain. Water-bearing.	Three connected main lines, and secondary branches; by wells in the chalk.
H^2	668,000	251,500	26	Neocomian... ... Oxford clay... ... Lower Oolite ...	Uncertain. Non-water-bearing Uncertain	Three connected main lines, and secondary branches; by wells in lower greensand and lower Oolite.
H^3	408,000	156,500	25	Chalk ... ... London clay ...	Water-bearing Non-water-bearing	Two connected main lines, and secondary branches; by wells in the chalk.
H^4	375,000	325,000	25	Chalk ... ... London clay ...	Water-bearing. Non-water-bearing.	One main line and secondary branches; by wells in the chalk, and partly by surface collection.
H^5	631,000	264,000	23	Necomian ... ... Chalk	Uncertain. Water-bearing.	Three connected main lines and secondary branches; by wells in and down to the chalk.
H^6	467,000	220,000	23	London clay ...	Non-water-bearing (water-bearing beds beneath.)	One main line and secondary branches; by wells down to lower London tertiaries, and partly by surface collection.
H^7	408,000	84,000	23	Chalk ... ... London clay ...	Water-bearing. Non-water-bearing.	Two disconnected main lines and branches; by wells down to lower London tertiaries, and partly by surface collection.
H^8	622,000	220,000	22	Chalk (mostly covered by drift) ... London clay ...	Water-bearing. Non-water-bearing.	Two disconnected main lines, with one branch and secondary branches; by wells down to the chalk, and by surface collection.
H^9	486,000	188,000	23	Chalk (mostly covered by drift) ...	Water-bearing.	Two connected main lines and secondary branches; by wells down to the chalk, and by surface collection.
H^{10}	500,000	200,000	23	Chalk (mostly covered by drift) ...	Water-bearing.	One main line, with three branches and secondary branches; by wells down to the chalk, and by surface collection.
H^{11}	310,000	125,000	23	Chalk (mostly covered by drift) ...	Water-bearing.	Main line and secondary branches; by wells down to the chalk, and by surface collection.
I^1	679,000	210,000	35	Neocomian... ... Chalk ... ... Eocene	Uncertain. Water-bearing. „	Two connected main lines, with one main branch and secondary branches; by wells in chalk, and in eocene beds on the S.
I^2	361,000	170,000	35	Chalk ... ... Eocene	Water-bearing. „	Three connected main lines and secondary branches; by wells in chalk, and in eocene beds on the S.
I^3	402,000	206,000	30	Chalk ... ... London clay ... Bagshot	Water-bearing. Non-water-bearing. Water-bearing.	Main lines and secondary branches; by wells in the chalk; in Bagshot beds on the N.
I^4	804,000	413,000	35	Neocomian... ... Chalk ... ... Eocene	Uncertain. Water-bearing. „	By two connected main lines, with three branches and secondary branches; by wells in the chalk and lower greensand.
I^5	549,500	557,000	30	Neocomian... ... Chalk ... ... Weald clay... ... London clay ...	Uncertain. Water-bearing. Non-water-bearing. „	Three main lines and secondary branches; by wells in chalk and lower greensand.
I^6	467,000	428,000	32	Neocomian... ... Chalk ... ... London clay ...	Uncertain. Water-bearing. Non-water-bearing.	Main lines, with three branches and secondary branches; by wells in the chalk and lower greensand.
I^7	98,000	66,000	35	Wealden ... ... Cretaceous ... ... Eocene	Uncertain. „ Water-bearing.	Main line and secondary branches; by wells and surface collection.
K^1	390,000	150,000	34	Hastings beds. ... Neocomian... ... Weald clay... ... Chalk	Water-bearing. Uncertain. Non-water-bearing. Water-bearing.	Four connected main lines and secondary branches; by wells in the chalk, lower greensand, and Hastings beds.

* "Local Government Directory."
† Each inch of rainfall represents 100 tons of water per acre. Compiled from report of Rivers Pollution Commission.
‡ Report of Rivers Pollution Commission.



Map of Districts Proposed by Professor Ansted.

TABLE II.—(*Continued.*)

	Area in acres.*	Population.*	Average Rainfall in inches.†	Geological Formations.‡	Water-bearing or otherwise.‡	Mode of Supply; described generally in the "Suggestions."
K^3	558,500	348,000	33	Hastings beds ... Neocomian ... Weald clay... Chalk ...	Water-bearing. Uncertain. Non-water-bearing. Water-bearing.	Main line and secondary branches; by wells in the Hastings beds, and on the S. in chalk and lower greensand.
L^1	309,000	184,000	33	Oxford clay ... Lias ... Lower Oolites ...	Non-water-bearing. " Uncertain.	Three main lines and secondary branches; partly by wells in and down to lower Oolite, and partly by surface collection.
L^2	500,000	250,000	29	Bunter ... Oxford clay ... Lias ... Lower Oolites ...	Water-bearing. Non-water-bearing. " Uncertain.	Main line with secondary branches; partly by wells in and down to lower Oolites, and partly by surface collection; auxiliary wells in bunter on W.
L^3	450,000	185,000	36	Bunter ... Lias ... Lower Oolites ...	Water-bearing. Non-water-bearing. Uncertain.	Two connected main lines, and secondary branches; by wells in lower Oolite on E., and bunter on W., partly by surface collection.
L^4	450,000	142,000	36	Oxford clay ... Chalk ... Eocene ...	Non-water-bearing. Water-bearing. "	Three connected main lines and secondary branches; by wells in the chalk and eocene beds.
M^1	882,000	356,000	48	Igneous ... Old red ... Millstone grit ...	Non-water-bearing. Uncertain. "	Main line and secondary branches; chiefly by surface collection.
M^2	542,000	296,000	52	Igneous ... Old red ... Millstone grit ...	Non-water-bearing. Uncertain. "	Main line and secondary branches; chiefly by surface collection; auxiliary wells in millstone grit.
M^3	890,000	240,000	58	Igneous ... Old red ... Millstone grit ...	Non-water-bearing. Uncertain. "	Three main lines with two branches and secondary branches; chiefly by surface collection; auxiliary wells in old red sandstone.
M^4	403,000	181,000	35	Old red ... Bunter ...	Uncertain. Water-bearing.	Two disconnected main lines and secondary branches; by wells in bunter, and by surface collection.

* "Local Government Directory."
† Each inch of rainfall represents 100 tons of water per acre. Compiled from report of Rivers Pollution Commission.
‡ Report of Rivers Pollution Commission.

ESSAY BY PROFESSOR ANSTED, F.R.S.

MOTTO.—"Water, water, everywhere,*
And not a drop to drink."

A systematic division of our country into districts for water supply, presumes the existence of a map in which the lines of water-parting between the river basins are marked, and the included areas are calculated. A map of this kind, prepared by Mr. Petermann, was published many years ago, and was accompanied by references to the rainfall in different parts of the country as then determined. This map was on a small scale (25 miles to an inch), and referred only to the larger catchments. Very similar maps were afterwards prepared and published in the Appendix to the Report of the Duke of Richmond's Commission, and again in the Sixth Report on the Pollution of Rivers. One of these, marked with lines of water-parting and notices of rainfall, was coloured geologically. These and maps prepared for the Reports on the Fisheries, are among the published evidence that will be referred to.

The most important map in reference to the subject is that published by the Ordnance Survey, entitled, "Rivers of England and their Catchment Basins." This map is drawn to a scale of 10 miles to an inch, the maps just referred to being 25 miles to an inch. In it the whole of England and Wales is parcelled out into 215 districts, which vary in area from three square miles to 4,613. Of the whole number more than 60 are drainages of small unnamed streams or tracks, having no drainage system. Of named streams a considerable number are small, unimportant, and have no urban population.

Of the remainder, about 70 consist of complete river basins. The rest are basins either of independent streams or tributaries, but include adjacent tracts between the mouths of adjoining basins. In this map the area of each district is calculated, and the rainfall as given by Mr. Symons' returns, is indicated at a large number of stations throughout the different catchments.

It may be observed, with regard to this map, that no attempt is made to group the districts, that the areas of some of the complete river basins and of some tributaries do not agree with other measurements made carefully by engineers for special purposes and published, and that the rainfall records are imperfect and require revision. Notwithstanding these drawbacks, the Ordnance Survey river map must, at present, be referred to as the basis of any practical system of grouping river basins for water supply.

A work of my own, on "Water and Water Supply," recently published, contains a systematic account of the various catchments of the British Islands, arranged in 18 principal groups, eight of them English, and much information on the general subject of the distribution of surface waters. It contains, also, a number of estimates of the areas of catchments, and of portions of the larger river basins, and many references to the geology and topography of the basins.

In the published account of the Water Congress of last year, at the Society of Arts, there are suggestions by several authorities as to the grouping of the catchments for special purposes. The following are the most important:—

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* Two essays were sent in under this motto.

Mr. Conder suggests 10 groups, varying in area from 2,500 to 9,400 square miles, and in population from 1½ to 5 millions, but gives no details.

Mr. De Rance proposes 14 groups, varying greatly in extent, and not clearly defined. The area in each district occupied by rocks of the same geological age is stated, and also the area in each presumed to have permeable strata at the surface.

Mr. Parry advises a division of the country into 15 to 20 districts, as a proper number to admit of the supervision of each for water supply, by an engineer to be appointed for that purpose. He does not, however indicate his proposed groups.

Mr. Shelford points out that a large proportion of the so-called catchment basins of the Ordnance Survey river map being within one, two, or three counties, might conveniently be grouped and brought under existing jurisdiction, 11 important rivers being left for special consideration. No method of grouping is suggested.

A large amount of valuable information, concerning the subject now under consideration, exists in the Reports of Commissions, already referred to, and in other Parliamentary and official documents, but the author is not aware of other special suggestions concerning the grouping of catchments, than those just alluded to.

Under these conditions of published evidence, the following suggestions are offered:—

SURFACE WATERS.

1. To divide England and Wales into principal districts, each consisting either of one complete river basin, or of a group of adjacent river basins under similar physical conditions. Such a division is attempted in a tabular statement appended (see p. 53), and indicated in the accompanying map. Of the districts suggested, six are principal river basins, namely, the Thames, the Severn, the Ouse, the Trent, the Mersey, and the Ribble, the importance of the last two being due, not so much to the extent of their drainage area, as to the magnitude and number of the towns included within them. Five are groups of small adjacent catchments, within which are comparatively few large towns, and which have a small urban population. One group comprises three principal rivers, all entering the sea by a common estuary, the Wash; and one comprises the river basins of Durham and Northumberland, which have important natural relations, and form a convenient group. Of these 13 divisions, the statement referred to shows, in each case, (1) the total drainage area included, (2) the mean annual rainfall over the whole area, (3) the total urban population, estimated from the population of towns of 1,000 inhabitants or upwards, according to the last census; and (4) the proportion of urban population to each square mile of drainage area.

2. To subdivide these districts into convenient and natural groups of moderate extent. In the case of the great rivers, many tributaries may be regarded as independent catchments, while others group themselves without inconvenience. The large groups of small catchments may be conveniently broken up into smaller groups. The sub-division thus suggested is attempted in Appendix I. to this memoir. In the tables here submitted there are 43 districts, of each of which the following particulars are given:—(*a.*) The geographical position of the river, tributary, or group of streams. (*b.*) An account of the geology of that part of the principal drainage area included, indicating especially the rocks in which the streams originate, those over which they flow, and the general nature of the drainage area. (*c.*) The extent of the drainage area included, stated in square miles. The authority for the figures is the Ordnance Survey map of rivers, corrected and modified in many cases by other published statements. (*d.*) The mean annual rainfall over the district, obtained by averaging the records within the drainage area published in the Ordnance Survey map. (*e.*) Urban population of the district. The areas included in these sub-groups, with the single exception of the catchment basin of the Great Ouse, are less than 2,000 square miles in extent, and all are above 500 square miles.

3. To tabulate the names, relative position, and extent of drainage area of all the streams in England and Wales, whether primary or tributary, within whose catchment areas there is any urban population, and to estimate the amount of such population with regard to each stream. The tabular statements offered in Appendix II. have been prepared to supply the facts required to carry out this suggestion. The catchment areas are, however, only given approximately, except in those cases where accurate measurements have been published, or where the rivers are referred to in the Ordnance Survey river map. The names of the principal or primary tributaries of the large rivers are given in these tables, but the names of many of the secondary feeders of importance will be found in Appendix III. It has been thought expedient in these tables to state the extent of country not included within the catchments, but estimated in the totals of drainage area of each sub-district.

4. To tabulate the names, position with regard to natural drainage and natural river basin, and population of all the towns in England and Wales of more than 1,000 inhabitants. The tabular statements in Appendix III. have been prepared to meet this suggestion. The number of towns tabulated is nearly 1,000, and they are so arranged as to indicate the position of each with regard to the river basins of the country, and with regard to other towns on the same stream.

5. The divisions and sub-divisions here proposed being accepted, it would be desirable, for the purpose of water supply, to collect and tabulate as many trustworthy analyses of the waters of each stream as can be obtained. A very large number of such analyses will be found in the Sixth Report on the Pollution of Rivers, others have been published in the work quoted on "Water and Water Supply," and others would be obtained from distinguished chemists.

6. A complete alphabetical index of the streams and towns mentioned in the lists and tables here suggested would be desirable for reference, should the suggestions be adopted.

7. A map on the scale of the Ordnance Survey

river map, in which the position of every town and every stream is marked, and in which the divisions and sub-divisions adopted are duly inserted, would be of great interest and value for reference.

UNDERGROUND WATERS.

A supply of pure water to many towns, and to villages and collected populations not numbering 1,000 souls, must frequently depend on the possibility of reaching underground sources, and the cost incurred in rendering these sources available. It is suggested, however, that no division of our country into districts, other than those marked by certain colours on geological maps, would be of practical use, and as such maps are well-known, it is not thought necessary to append one to the present memoir.

It addition to the great geological map of the survey, on a scale of one inch to a foot, and the reduced maps by Professor Ramsay and others, maps of small portions of the country have been prepared by Mr. Lucas as hydrogeological maps, which are of use to those who are seeking water in certain rocks.

Should the general suggestions for a division of the country into groups here recommended be adopted, so far as surface waters are concerned, it would be desirable to supplement the tables given by preparing a list of the smaller populations situated on or near permeable and water-yielding rocks, and mark their position on a map on which the presence of permeable or impermeable rocks is indicated by a tint. According to the estimate of Mr. De Rance, about 20,000 square miles of England consist of permeable rock, nearly 9,000 being chalk, and nearly 7,500 triassic sandstone. The suggestions required by the Council do not, however, seem to extend to this part of the subject of water supply.

APPENDIX I.

STATEMENT OF SUB-GROUPS OF CATCHMENTS IN ENGLAND AND WALES, INDICATING THE GEOGRAPHICAL POSITION, GEOLOGY, RAINFALL, DRAINAGE AREAS, AND URBAN POPULATION OF EACH GROUP.

GROUP A.—THE BASIN OF THE THAMES.

Statement of the sub-divisions of the basin, showing the geographical limits, the geology, the mean annual rainfall, and the extent of drainage area of each.

Geographical Limit.	Geology of the District.	Drainage Area in Square Miles.	Mean Annual Rainfall in Inches.	Urban Population in Area.
Upper Basin.				
a. The river from its sources to the gorge of the Thames near Pangbourn, including the early tributaries as far as the Tame.	All the early feeders of the Thames, as far as Oxford, originate in the Lias or lower Oolites of the Cottswolds, and flow entirely over similar rocks. Some of them run for a considerable distance over the Lias between banks of Oolitic rock. Below Oxford the river is joined by the Ock and the Tame. Both rise in the lower cretaceous rocks, but chiefly flow over Oolites; the Tame, however, passes through a tract of lower and upper greensand and gault before reaching the Thames	1,800	28·0	128,000
Middle Basin.				
b. The river from Pangbourn to Teddington, with the tributaries on both banks.	The tributaries on the north rise in and flow over the chalk, the Coln passing for a short distance over London clay near its junction with the Thames. The others rise in cretaceous rocks, but flow chiefly over London clay, and eocene sands. Below Reading the Thames flows exclusively over London clay	1,850	26·2	315,000
Lower Basin.				
c. The river from Teddington to the sea, with the tributaries.	The tributaries from the north rise in and drain for some distance the chalk, some of them only entering the London clay near the river. The lower part of the Lea, and the whole of the Roding, the Ingerburn, and the Crouch, are exclusively in the London clay. The southern tributaries rise in lower cretaceous, or Wealden rocks, traverse a considerable breadth of chalk, and then pass over London clay, of which they draw a large area. The Ravensbourne flows entirely over London clay, and he Darent chiefly over chalk ...	1,675	26·3	3,731,000
		5,425		5,174,000

N.B.—The number of stations at which the rainfall is recorded is 56, of which 12 are in *a*, 23 in *b*, 6 in *c*, and 15 in *d*.
The mean annual rainfall of the district is 26·6 inches.

APPENDIX I.—(*Continued.*)

GROUP B.—RIVER BASINS SOUTH OF THE THAMES.

Statement of the sub-groups of catchments; indicating the geographical limits, the extent of drainage area, the geology of the district, the mean annual rainfall, and the urban population in each sub-group.

Limits of Sub-Groups.	Geology of the District.	Area of Catchment in Square Miles.	Rainfall in Inches.	Urban Population.
a. Basins of the Medway and the Kentish Stour, and the coast from Sheppey Island to Dover.	The sources of the Medway and its feeders and the early course are in the Hastings sand or Weald clay. The main stream after flowing through the Wealden rocks, crosses and drains the rocks of the cretaceous series, chiefly the lower greensand and chalk. The Beult, a principal feeder, is entirely confined to the Weald clay. The Stour is is almost entirely a chalk river, crossing a patch of London clay in the northern catchment area	1,254	26	284,000
b. Basins of the rivers entering the sea between Dover and the Selsea Bill, and the intervening coast.	The rivers of this group rise in the Wealden rocks and cross these rocks before entering the cretaceous series. The streams flow chiefly over chalk in the latter part of their course. The Rother is entirely in the Hastings sands, and the Ashbourne in the Weald clay. The Adur and the Avon, in their upper course, receive several tributaries from the Weald clay, the others from the Hastings sands	1,404	30	341,000
c. Basins of the rivers entering the sea between Selsea Bill and the mouth of the Avon.	These rivers all take their rise in, and flow at first over the chalk, but then enter and drain the eocene beds of South Hampshire in their course to the sea. None of the streams are important in an economic sense, their course over the chalk not yielding a large flow of water. The tertiaries of the South Hampshire basin include extensive beds of sand	1,206	30·1	250,000
d. Basins of the Avon (Hants and Wilts) and Stour (Dorset).	The Avon rises in the lower cretaceous beds close to the southern rim of the Thames basin. It soon enters the chalk and flows over that rock for a long distance in Wiltshire, draining its surface by feeders, of which the Wiley is the principal. It then enters and crosses the the Hampshire tertiary basin to the sea. The Stour rises in and drains a considerable breadth of Oolitic rocks	1,132	30·7	77,000
		4,996		852,000

N.B.—The number of stations at which the rainfall is recorded in the district is 61, of which there are 19 in *a*, 23 in *b*, 10 in *c*, and 9 in *d*. The mean rainfall of the whole district is 28·8 inches.

GROUP C.—RIVER BASINS OF THE SOUTH-WEST OF ENGLAND.

Statement of the sub-groups of catchments; indicating the geographical limits, the extent of drainage area, the geology, the mean annual rainfall, and urban population of each group.

Geographical Limits.	Geological Description of the District.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
a. Basins of the Frome (Dorset) and the Piddle, and of the small rivers between the mouth of the Frome and that of the Exe.	The Frome rises in the Oolites, and in the early part of its course is fed chiefly from the lower greensand. It then crosses the chalk for a considerable distance. The latter part of its course is over the Hampshire tertiaries. The Piddle has a parallel course over similar rocks. The small streams as far as Bridport are on the Oolites. The Brit and Char on the Lias. The others flow in valleys cut into the new red sandstone, draining the overlying lower greensand.	752	32·2	67,000
b. The basin of the Exe.	The Exe rises and flows for some distance over the altered old red sandstone or Devonian series of North Devon, one of its tributaries (the Barle) being entirely Devonian. It then crosses a small breadth of middle carboniferous rock, and enters the new red sandstone, which it flows over, and drains by several feeders, for the rest of its course.	584	37·3	77,000
c. The basins of the Teign and the Dart, and small streams entering the sea between the Exe and the Tamer.	All these rivers proceed from and drain the granite of Dartmoor. Leaving the granite, they all, with the exception of the Teign, flow over and drain the Devonian rocks of South Devon. The Teign crosses and drains the new red sandstone in the lower part of its course....	638	47·5	139,000

APPENDIX I.—GROUP C.—(*Continued.*)

Geographical Limits.	Geological Description of the District.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
d. The basins of the Tamer and the Tavey, and that of the St. German's river (Lynher).	The Tamer rises in and flows for a long distance through the Devonshire representatives of the millstone grit, known as the culm measures. It then enters and crosses the limestones and slates of the Devonian period to the sea. The Tavy rises on the Dartmoor granite, and flows over the Devonian slates and limestones to the sea. The Lynher, or St. German's river, rises in the granitic boss of Brown Willey and Rough Tor, and flows entirely over Devonian rocks.	570	50·2	83,000
e. The basins of the Cornish rivers.	These streams, the Fowey and Fal in the south, and the Alan or Camel in the north, being the only ones of importance, rise in the granitic bosses of Cornwall, and drain the slates, schists and other metamorphic Devonian rocks of that county. North of the Camel, the coast drainage is over the culm measures.	1,311	42·5	92,000
f. The basins of the Torridge and the Taw.	Both these rivers rise on the northern slopes of Dartmoor, and immediately enter the culm measures, which they cross and drain. Almost the whole of their course and drainage are on these rocks, but some of the feeders of the Tawe proceed from the Devonian schists of North Devon.	848	50·3	41,000
g. The basins of the Parret, the Brue, and the Axe.	The Parret and its early feeders from the south, rise in the hills of lower greensand and oolitic rock, or from the lias on the borders of Devonshire. The River Brue flows entirely over lias, and several feeders of the Parret drain the same rock. The western tributaries of the Parret, however, cross the new red sandstone, rising in the Devonian slates. The Axe rises in the mountain limestone of the Mendips. As they approach the Bristol Channel, all these rivers flow over a large flat alluvial tract.	1,116	34·0	74,000
		5,809		578,000

N.B.—The rainfall is estimated from the records over 59 stations, and the mean is 41·3 inches. The stations are:—8 in *a*, 6 in *b*, 9 in *c*, 5 in *d*, 13 in *e*, 7 in *f*, and 11 in *g*.

GROUP D.—BASIN OF THE SEVERN.

Statement of the principal sub-groups of tributaries, indicating their geographical limits, the geology, the extent of drainage area, the mean annual rainfall, and the urban population of each.

Limits of Sub-Group.	Geographical Description of the District.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
a. The Upper Severn and the basin of the Vyrnwy.	The country consists entirely of hard slates, schists, and metamorphic rocks of cambrian or silurian age, chiefly upper silurian	1,820	63·7	22,000
b. The tributaries and country on the left or north and east bank of the Severn, between the basin of the Vyrnwy and that of the Upper Avon.	Almost all the tributaries flow through and drain for the greater part of their course the upper and lower sandstones of the triassic period, which are, however, interrupted by the presence of permian sandstones, and the coal measures rising through them. The Perry rises in the Denbighshire coal-field, and crosses the bunter, or lower new red. The Tern, though chiefly confined to the trias, touches the coal-fields of Shropshire and South Staffordshire. The Worf drains chiefly the permian grits. The Stour, originating in the Dudley coal-field, chiefly drains the upper new red sandstone. The Salwarp crosses the same rock, though draining part of the lias	820	26·2	194,000
c. The Teme and small tributaries on the right bank of the Severn to the water-shed of the Wye.	The small brooks, and other feeders of the Severn between the Vyrnwy and the mouth of the Tern, drain a broken district of silurian, Devonian, carboniferous, and permian rocks, containing a very small urban population, and yielding little water to the river, except in flood time. The Teme and its feeders drain a large district of metamorphic slates, grits, and schists, chiefly of the silurian period	893	25·4	56,000

APPENDIX I.—GROUP D.—(*Continued.*)

Limits of Sub-Group.	Geographical Description of the District.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
d. The sub-basin of the Upper Avon.	This important tributary rises in the lias of Warwickshire, but soon enters the upper new red sandstone, and crosses the permian grits at the southern extremity of the Warwickshire coal-field. Passing again into, and crossing the new red, it once more enters the lias, and continues in that rock for the most part till it joins the Severn. It chiefly drains the lias	1,050	26·7	104,000
e. The sub-basin of the Lower Avon, and the small sub-basins between the Upper and Lower Avon.	Between the basins of the Upper and Lower Avon, the Cottswold hills approach the banks of the Severn, and there is only a narrow belt of lias intervening drained by the Chelt and some smaller streams. A large part of the drainage area of the lower Avon is in the oolites, beyond the edge of the Thames basin, and the river then crosses the lias and new red sandstone to the Bristol coal-field, which it drains	1,280	37·5	348,000
f. The sub-basin of the Wye, and the small basins on the right bank of the Severn adjacent.	The Wye and its chief tributary, the Lug, originate in and drain the altered silurian rocks of Wales, and the characteristic and typical old red sandstone grits and conglomerates of Herefordshire and Monmouthshire. Below Ross the Wye drains the Forest of Dean coal-field, and crosses a small belt of carboniferous limestone to reach the Severn	1,709	32·0	58,000
g. The sub-basins of the Taff and Usk, and small basins adjacent.	The Usk drains only the old red sandstone grits and conglomerates for a long distance, and then, fringing the mountain limestone that encloses the South Welsh coal-field, it receives some of the drainage of that district by small tributaries. The Taff rises in and drains the eastern part of that large coal-field crossing the old red sandstone to reach the Severn.	1,007	46·0	148,000
		8,018		930,000

N.B.—The mean annual rainfall of the Severn basin, is 37·5 inches. The number of stations at which rainfall is recorded is 66, of which there are in a—7; *b*—7; *c*—4; *d*—15; *e*—10; *f*—10; *g*—13.

GROUP E.—RIVER BASINS OF THE WELSH COAST.

Statement of the sub-groups of catchments, indicating their geographical limits, geology, drainage-area, average rainfall, and the urban population of each.

Limits of Sub-Groups.	Geological Description of the Drainage Area.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
a. Rivers draining south.	The basins of the rivers of this sub-group may be further sub-divided into two; the eastern, in which the country drained, consists of the South Welsh coal-field; and the western, commencing with the Towy, comprising the altered rocks of the older palæozoic series. All the streams of the former rise in the grits and conglomerates of the old red sandstone, and cross a narrow belt of carboniferous limestone before entering and on emerging from the coal measures. Of the western rivers, the Cleddâu crosses the Pembrokeshire extension of the coal-field...	1,936	43·8	136,000
b. Rivers draining west.	The whole of the western drainage of Wales is by torrents, which commence their course on the western slopes of the Welsh mountains, and flow entirely over the slates, schists, and altered rocks of that part of Great Britain. They cross no unaltered sedimentary rocks	1,044	56·6	37,000
c. Rivers draining north.	Of these the Conway and the Clwydd rise in the same metamorphic and igneous rocks as those of the former group, and cross silurian and cambrian slates and schists. The Dee rises in and crosses similar rocks for a long distance, but then crosses the Denbighshire coal-field to the lower new red sandstone, over which rock it continues to flow till its bed opens out into the wide estuary of the Dee	4,476	38·4	131,000
		4,456		304,000

N.B.—The mean annual rainfall as obtained from 34 stations in various parts of the drainage area of this group is 47·2 inches. The number of stations in the southern district 8, in the western district 14, and in the northern district 12.

APPENDIX I.—(*Continued.*)

GROUP F.—BASINS OF RIVERS DRAINING INTO THE WASH.

Statement of the river basins, and of the geology, mean rainfall, drainage area, and urban population of each.

Names of the River Basins.	Geology of the Catchment Area.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
a. The basin of the Great Ouse.	The early feeders of this river rise in and drain the lower oolites and the lias, but other tributaries soon join it, whose source is in lower cretaceous rocks or chalk. Crossing the lower oolites, the main stream flows for a long distance over the middle oolites, chiefly Oxford and Kimmeridge clay, with very little intervening limestone. From Huntingdon to the mouth of the river, the whole course is through low alluvial lands, the stream being fed by affluents from the Norfolk chalk.	3,021	24·0	171,000
b. The basins of the Nen and Welland.	The Nen rises on the oolites, but flows almost entirely over the lias, the river valley being cut through the oolitic rocks. Like the Great Ouse, the lower part of the river course is through the alluvial lands forming the fen district. The Welland rises near the Nen, and like it flows over and drains the lias till it enters the fen country. The rest of the course is over alluvial clays.	1,837	24·1	156,000
c. The basins of the Witham, and of the parts of Lincolnshire between the Witham water-shed and the eastern coast.	The Witham rises in and flows for a considerable distance over the lias, having a northerly course near the escarpment of the oolites. It then enters the fens, but receives feeders from the oolitic limestones and clays on each side. Its course from Lincoln to the outfall in the Wash is entirely over the flat lands of the fen district. The Steeping river, and other small streams, rise in the eastern side of the escarpment of the lower greensand, and drain that rock and the chalk, passing then through a belt of alluvium to the sea...	1,508	24·9	69,000
		6,366		396,000

N.B.—The mean rainfall of the whole district, estimated from observations at 58 stations, is 24·2 inches. Of these stations, 34 are in sub-group *a*, 16 are in *b*, and 8 in *c*.

GROUP G.—THE RIVER BASINS OF THE EASTERN COUNTIES.

Statement of the groups of rivers, their geology, drainage area, rainfall, and urban population.

Geographical Limits of Sub-Groups.	Geology of the Districts.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
a. River basins of Essex and Suffolk.	The Chelmer, and the Pant or Blackwater, uniting in the estuary of the Blackwater, and the River Colne, take their origin in the chalk, but flow over and drain the beds of the London clay. The Stour and its principal feeders not only rise in but drain a large area of chalk before entering the London clay, but the whole of the lower part of their course is over that rock. The older tertiaries are much covered with gravel. The Suffolk rivers also flow over and drain a large area of chalk. In their lower course, the London clay is covered with the newer tertiary beds called "crag," and the rivers drain entirely this open shelly rock...	1,741	23·9	156,000
b. River basins of Norfolk.	These drain chalk almost exclusively, the patches of crag and London clay being small in extent and near the coast. The river valleys are generally in narrow breadths of tertiary rock, chiefly crag. Throughout the Eastern counties the rocks are much covered by gravel and superficial deposits, many of which hold back the water and admit of numerous land springs	1,481	25·5	176,000
		3,222		333,000

N.B.—The mean rainfall of the whole district is 24·7 inches, obtained from records at 33 stations. Of these 15 are in Essex and Suffolk, and 18 in Norfolk.

APPENDIX I.—(*Continued.*)

GROUP H.—THE BASIN OF THE TRENT.

Statement of the sub-divisions of the basin, and of the geographical limits, the geology, the drainage area, the rainfall, and the urban population in each group of sub-basins.

Geological Limits of Sub-Basins.	Geology of the District.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
a. The Upper Trent, and the sub-basin of the Tame.	The Trent rises in the North Staffordshire coal-field, which it drains by several feeders. It then crosses and drains the permian grits and sandstones, and enters the keuper, or upper member of the new red sandstone, which it crosses, and drains as far as the confluence of the Tame. The Tame rises in the South Staffordshire coal-field, and is fed by tributaries passing near or through the great manufacturing and industrial towns of that part of England. By other tributaries it drains the Warwickshire and Leicestershire coal-fields. A large part of its course is over the upper new red sandstone, consisting of marls and sandstones.	1,260	26·8	865,000
b. The sub-basins of the Derwent and the Dove, and the intervening parts of the Trent.	The sources of the Dove, and its tributary the Churnet, are in the North Staffordshire coal-field and the millstone grit; and the Dove flows through a considerable distance of millstone grit and carboniferous limestone before reaching the new red sandstone, near Ashbourne. Beyond this its course is entirely in the upper new red or keuper sandstone. The Derwent is almost exclusively a millstone grit river, draining a part of the south-western extremity of the South Yorkshire coal-field. It then enters the new red sandstone of the valley of the Trent.	1,000	29·9	142,000
c. The sub-basin of the Soar.	Except the metamorphic rocks of Charnwood Forest, the Soar is a river flowing over and draining only the lias and new red sandstone. Its important feeders, including the Wreak, rise in and flow over the lias, but the main stream is confined to the keuper beds of the new red sandstone.	539	25·8	123,000
d. The Lower Trent, including the sub-basins of the Devon and the Idle.	After receiving the Soar, the Trent and its lower feeders flow through the new red sandstone, very near the escarpment of the lias. The Lean, from the north, drains the south-eastern part of the South Yorkshire coal-field and the permian rocks. The Devon and its tributary the Smite, are confined to the lias and the keuper sandstones. The tributaries of the Idle rise in the permian rocks, and flow over the lower new red sandstone, or bunter. The main stream of the Lower Trent flows altogether over the keuper.	1,260	25·8	147,000
		4,062		1,277,000

N.B.—The mean rainfall over the whole area, obtained from records at 39 stations is 27·35 inches. There are 9 stations in *a*, 10 in *b*, 8 in *c*, and 12 in *d*.

GROUP I.—THE BASINS OF THE OUSE AND HUMBER.

Statement of the various sub-groups of tributaries, and of the geology, the rainfall, and the urban population of each sub-group.

Groups of Tributaries.	Geology of District.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
a. The sub-basins of the Swale and the Ure.	The Swale rises in the millstone grit on the higher slopes of the Pennine hills, and flows through narrow ravines in the mountain limestone to Richmond. Soon after it enters the new red sandstone. The Ure has a similar course to Masham. It then crosses the permian grits and limestones before reaching the new red sandstone near its confluence with the Swale.	950	36·3	24,000

APPENDIX I.—GROUP I.—(*Continued.*)

Groups of Tributaries.	Geology of District.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
b. The sub-basins of the Nidd and he Wharfe, and the course of the use to the confluence of the Wharfe.	The greater part of the course of the Nidd is in the millstone grit, the bed of the stream reaching the mountain limestone. Near its junction with the Ouse it crosses the permian rock and the new red sandstone. The Wharfe crosses and drains a considerable tract of mountain limestone, then entering the millstone grit, and crossing the permian and triassic rocks like the other early tributaries of the Ouse. In all this district the rocks of the carboniferous system include many bands of shale, and are generally much fractured. The valleys are often occupied by boulder clay, which is in some places widely spread.	892	35·3	60,000
c. The sub-basin of the Aire and alder.	This important district includes the northern part of the Yorkshire coal-field, and many large manufacturing towns. A large part of the Aire, however, and the upper part of the Calder, drain the middle carboniferous rocks of the millstone grit series. The Aire enters the coal measures near Bingley, and only drains a small part of the northern extremity of the coal-field. The Calder crosses similar rocks for some distance to the south. The two streams unite as the Aire leaves these rocks, and the united stream crosses the permian into the new red sandstone on reaching the valley of the Ouse...	815	35·5	676,000
d. The sub-basin of the Don.	The Don, like all the tributaries of the Ouse entering from the right, rises in the middle carboniferous rocks, but, unlike the others, enters the coal measures immediately, and the main stream, and all its early feeders, drain that part of the series almost exclusively. A little before reaching Doncaster it crosses the permian rocks, and there enters the new red sandstone. It enters the Ouse through a wide tract of low alluvial delta, in which its waters join those of the River Trent. ...	682	31·4	354,000
e. The sub-basin of the Derwent.	The Derwent, by numerous tributaries, originates in the oolitic hills of the north-east of Yorkshire, the river valleys being in the lias. Draining in this way a wide breadth of country, the feeders unite a little above Maldon, and thence proceed southward, crossing the lias into the new red sandstone. The stream then flows parallel to the Ouse in the new red sandstoue valley and reaches the Ouse a little above the confluence of the Aire	814	27·3	19,000
f. The basin of the Humber.	The Humber, regarded as a separate basin, drains a breadth of low flat land extending from the escarpment of the lias to the sea. It flows over representatives of all the oolitic and cretaceous rocks, but a large part of the basin towards the sea is low-lying and alluvial. The drainage is effected by the Hull river on the north, and the Ancholme, or New River, on the south.... ...	1,253	23·6	194,000
		5,433		1,327,000

N.B.—The mean annual rainfall over the whole district, estimated from observations at 56 stations, is 31·2 inches. Of these, 6 are in *a*, 7 in *b*, 14 in *c*, 10 in *d*, 7 in *e*, and 12 in *f*.

GROUP K.—THE BASIN OF THE MERSEY.

Geology of the Drainage Area.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
The early feeders of the Mersey originate in the middle carboniferous rocks or millstone grit of the Penine chain, and, after uniting, cross the southern part of the Lancashire coal-field into the new red sandstone, chiefly the bunter or lower member. The Irwell, the principal feeder from the north, here joins, having drained a large and important part of the coal-field, by several tributaries passing thickly-peopled towns and districts. The lower part of the Irwell drains part of the bunter sandstone. The Bollin and the Weaver, the important feeders of the Irwell from the south, drain parts of the North Staffordshire coal-field, but flow chiefly through and drain the keuper or upper member of the new red sandstone. The whole of the lower part of the course of the Mersey is over the bunter, except that the Sankey drains part of the south-western extremity of the Lancashire coal-field.	1,724	37·0	1,225,000

N.B.—The rainfall of the Mersey basin is estimated from records kept at 27 stations.

APPENDIX I.—(*Continued.*)

GROUP L.—THE BASINS OF THE RIBBLE AND THE WYRE.

Geology of the Drainage Area.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
The whole of the Upper Ribble, and all its feeders to the Hodder, as well as the Hodder itself, flow over rocks, chiefly limestone and slate, of the old carboniferous series. The Calder flows over and drains the coal measures, and the Darwen and Douglas, important tributaries, rise in coal measures and millstone grit, but cross and drain chiefly the new red sandstone, at first the bunter, but near the mouth of the river crossing the keuper. The Wyre rises in the millstone grit, and is largely fed from that rock, but the whole of the lower part of its course is over the upper new red sandstone, till approaching the sea, it reaches and traverses a wide tract of alluvium.	1,088	39·7	[illegible]

N.B.—The rainfall of the Ribble and Wyre is estimated from observations recorded at 9 stations.

GROUP M.—THE RIVER BASINS OF THE LAKE DISTRICT.

Statement of the groups of basins, their geographical position, geology, rainfall, and urban population.

Limit of Sub-Group.	Geology of the District.	Drainage Area in Square Miles.	Rainfall in Inches.	[illegible]
a. The basins of the Lune and Kent.	These rivers take their rise in the altered palæozic slates, schists, grits and limestones of Cumberland and Westmoreland, and flow over them for some distance. After crossing the silurian rocks, the Lune enters the mountain limestone, and reaches the sea, draining that rock. The Kent flows through a valley in the mountain limestone	673	44·8	[illegible]
b. The catchment of the rivers from the western water-shed of the Lake district.	These rivers all rise in the altered Cumbrian rocks of Cumberland and Westmoreland, which culminate in an irregular mountain group. As they approach the coast they cross a fringe of stratified rock, consisting in the south of keuper sandstone, and in the north of coal measures (the Whitehaven coal-field). The rivers flowing north cross first the coal measures, and afterwards the bunter, one or two of the smaller having their course almost entirely in these rocks not commencing in the Cumbrian	1,000	55·5	[illegible]
c. The basin of the Eden.	The Eden itself, and all its earlier feeders, rise in the middle and lower carboniferous rocks (millstone grit, and mountain limestone), and almost immediately enter the valley of the new red sandstone (keuper), through which the Eden flows throughout its course. One important tributary, the Eamont, rises in the lake mountains and expands into Ullswater lake before reaching the mountain limestone. As it approaches the sea, the river flows over the bunter, of which a small tract is laid bare, but the chief drainage is over keuper marls and sandstones	1,040	54·7	[illegible]
		2,713		[illegible]

N.B.—The mean rainfall over the district is 52·2 inches, obtained from observations made at 44 stations. Of these, 13 are
b-group *a*, 23 in *b*, and 8 in *c*. The mean rainfall in the lake district, excluding the valleys of the Lune and Kent is, howev-
ches, over more than 2,000 square miles, far the heaviest in the British Islands.

APPENDIX I.—(*Continued.*)

GROUP N.—THE RIVER BASINS OF DURHAM AND NORTHUMBERLAND.

tement of the sub-groups of catchments, their geographical position, drainage area, geology, rainfall, and urban population.

Limits of Sub-Groups.	Geology of the District.	Drainage Area in Square Miles.	Rainfall in Inches.	Urban Population.
The basins of the Esk and the s.	The basin of the Esk, though entirely in Yorkshire, must be regarded as forming an extension of that of the Tees. It drains the northern part of a district of lower Oolites and Lias forming the Cleveland hills, and of late years well known for the ironstone worked in the neighbourhood. The Tees rises in the millstone grit of the Penine hills, and its upper feeders are in the shales and grits of the middle and lower carboniferous system. In its lower part it crosses the Durham coal-field and Permian rocks to the upper beds of the new red sandstone, and below the junction of the Skerne drains the latter rock	1,032	22·3	145,000
The basin of the Wear.	The Wear rises in and drains the millstone grit, and then turning to the north, enters and traverses the coal measures. It afterwards turns east, and drains part of the magnesian limestone and permian sandstones, till it reaches the new red sandstone, which it crosses to the sea	456	25·2	202,000
The basin of the Tyne.	The greater part of the drainage of the Tyne, as of the other rivers of this part of England, is in the millstone grit. The river afterwards enters the coal measures, crossing and draining the most important part of the Newcastle coal-field to the sea	1,130	31·7	364,000
The smaller basins of North-erland.	These are several in number, but all rise in and drain similar rocks. The Blyth and the Wansbeck flow chiefly over coal measures. The Coquet is more a mountain limestone river, crossing however the northernmost extremity of the coal-field. Those further north are almost entirely mountain limestone rivers... ...	1,084	27·1	35,000
		3,702		746,000

B.—The mean rainfall, obtained from records at 34 stations, is 28 inches. Of these stations, 7 are in *a*, 6 in *b*, 11 in *c*, and 10 in *d*.

ABULAR STATEMENT OF THE PRINCIPAL GROUPS OF DRAINAGE AREAS IN ENGLAND AND WALES,

Shewing the total area included, the mean annual rainfall, and the urban population of each group.

References to the Groups.	Drainage Area in Square Miles.	Rainfall in Inches.	Total Urban Population.	Proportion of Urban Population to each Sq. Mile of Drainage Area.
The Basin of the Thames (excluding the Medway) ..	5,425	26·6	5,174,000	954
Basins of rivers south of the Thames Basin	4,996	28·8	852,000	170
Basins of rivers in the South-West of England	5,809	41·3	573,000	98
The Basin of the Severn........................	8,018	37·5	930,000	116
Basins of rivers draining the Welsh Coast	4,456	47·2	304,000	68
Basins of rivers entering the Wash	6,366	24·2	396,000	62
Basins of rivers of the Eastern Counties...........	3,222	24·8	333,000	103
Basin of the Trent	4,082	27·35	1,277,000	313
Basins of the Ouse, Trent, and Humber	5,433	31·2	1,327,000	244
The Basin of the Mersey	1,724	37·0	1,225,000	710
Basins of the Ribble and Wyre..................	1,088	39·7	350,000	321
Basins of rivers of the Lake District	2,713	52·2	168,000	62
Basins of rivers of Durham and Northumberland....	3,702	28·0	746,000	201

APPENDIX II.

NAMES, DRAINAGE-AREAS, AND URBAN POPULATION OF THE BASINS OF THE VARIOUS RIVERS AND TRIBUTARIES IN ENGLAND AND WALES.

A.
SUB-BASINS OF THE THAMES TRIBUTARIES.

Tributary.	Area in sq. miles.	Population.
a. UPPER BASIN.		
l Churn	73	8,000
l Coln	87	2,000
r Cole	48	14,000
l Leach Brook	36	2,000
l Bampton Brook	120	4,000
l Windrush	141	4,000
l Evenlode	189	16,000
l Cherwell	400	9,000
r Ock	120	3,000
l Thame	300	21,000
Intervening areas	286	..
b. MIDDLE BASIN.		
r Pang	30	1,000
r Kennet	400	23,000
r Lodden	110	3,000
l Wick	50	7,000
l Colne	450	49,000
r Wey	380	28,000
r Mole	200	30,000
r Hog's Mill	30	14,000
l Brent	70	40,000
Intervening areas	130	..
c. LOWER BASIN.		
r Wandle	60	86,000
r Ravensbourne	80	91,000
l Lea	600	61,000
l Roding	317	13,000
l Ingerburn	63	6,000
r Darent	314	18,000
l Crouch	181	4,000
Intervening areas	60	..

N.B.—The urban population on the river banks is 5,617,000, distributed as follows:—*a*, 45,000; *b*, 120,000; *c*, 4,452,000.

B.
RIVERS OF BASINS SOUTH OF THE THAMES.

Basins.	Area.	Population.
A. Medway	680	135,000
Stour (Kentish)	373	32,000
Coast and intervening areas	201	117,000
B. Rother	312	16,000
Ashbourne	121	3,000
Cuckmere	75	2,000
Ouse	205	15,000
Adur	160	36,000
Arun	370	26,000
Coast and intervening areas	161	143,000
C. Titchfield	85	4,000
Hamble	35	3,000
Itchen	231	87,000
Test	477	19,000
Lymington	91	5,000
Coast and intervening areas	52	131,000
D. Avon	673	66,000
Stour (Dorsetshire)	459	11,000

C.
RIVERS OF BASINS IN THE S.W. OF ENGLAND.

Basins.	Area.	Population.
A. Frome	187	8,000
Piddle or Trent	119	3,000
Wey	50	13,000
Brit	52	10,000
Lyme	39	2,000
Ax	165	5,000
Sid	21	4,000
Otter	82	8,000
Coast and small catchments	38	14,000
B. Exe	584	77,000
C. Teign	203	13,000
Dart	200	12,000
Aulne	54	2,000
Erme	43	4,000
Plym	59	71,000
Coast and small catchments	69	37,000
D. Tavy	85	8,000
Tamer	385	71,000
Lynher or St. German's	100	6,000
Looe	71	9,000
Fowey	120	2,000
Fal	50	14,000
Alan or Camel	149	9 000
Coast and small catchments	921	111,000
E. Torridge	336	14,000
Taw	455	20,000
Coast and small catchments	57	7,000
F. Parret	562	54,000
Brue	197	14,000
Axe	101	6,000
Coast and small catchments	256	..

D.
TRIBUTARIES OF THE SEVERN.

Tributaries.	Area.	Population.
A. Upper Severn	970	13,000
l Vyrnwy	350	9,000
B. *l* Perry	150	6,000
l Tern	250	21,000
l Worf	75	2 000
l Stour	150	111,000
l Salwarp	75	10,000
Intervening drainage	120	44,000
C. *r* Teme	660	9,000
r Small basins	222	47,000
D. *l* Upper Avon	1,050	104,000
E. *l* Small catchments	213	66,000
l Lower Avon	891	261,000
l Yeo	106	
F. *r* Leadon and small catchments:	100	6,000
r Wye	1,609	52,000
G. *r* Usk	540	44,000
r Taff	198	103,000
r Small catchments	269	

E.
RIVERS OF WELSH COAST BASINS.

Basins.	Area.	Population.
A. Ogmore	114	4,000
Afon	87	4,000
Neath	118	9,000
Tawe	106	52,000
Llwchwr	156	17,000
Gwendraeth Vawr	73	2,000
Towy	514	17,000
Taf	183	2,000
East Cleddau }	212	8,000
West Cleddau }		
Coast and small catchments	373	21,000
B. Teifi	386	8,000
Rheidol	75	7,000
Dovey	217	3,000
Mawddach	151	2,000
Seiont	143	9,000
Coast and small catchments	72	8,000
C. Conway	222	6,000
Clwydd	319	17,000
Dee	818	92,000
Coast and small catchments	117	16,000

F.
RIVERS DRAINING INTO THE WASH.

Basins.		Area.	Population.
A. Great Ouse.	Area.		
Tove	140	3,021	171,000
Ouzel	200		
Ivel	200		
Kym	100		
Cam	350		
Lark	200		
Little Ouse	350		
Wissey	240		
Nar	130		
Small basins and river	1,111		
B. Nen		1,077	107,000
Welland		760	49,000
C. Witham		1,079	51,000
Steeping River		101	18,000
Ludd		139	
Small catchments		189	

G.
RIVERS OF EASTERN COUNTIES BASINS.

Basins.	Area.	Population.
A. Chelmer } Blackwater	434	14,000
Pant }		17,000
Colne	192	32,000
Stour	407	26,000
Orwell or Gipping	171	48,000
Deben	153	7,000
Alde	109	7,000
Blythe	79	5,000
Small catchments	196	..
B. Waveney }	880	32,000
Wensum }		130,000
Bure	348	6,000
Small catchments	253	9,000

H.
TRIBUTARIES OF THE TRENT.

Tributary.	Area.	Population.
A. *r* Lyme	20	16,000
r Sow	234	26,000
l Blythe	62	1,000
r Tame	589	594,000
Intervening area	355	..
Population on river banks	..	86,000
B. *l* Dove	393	32,000
l Derwent	470	90,000
Intervening area	137	..
Population on river banks	..	20,000
C. *r* Soar	539	123,000
l Erewash	83	8,000
l Lean	53	4,000
r Devon	200	2,000
D. *l* Greet	50	2,000
l Idle	550	21,000
Intervening area	347	..
Population on river banks	..	110,000

I.
TRIBUTARIES OF THE OUSE AND HUMBER.

Tributaries.	Area.	Population.
Ouse.		
A. Swale	520	11,000
Ure	430	13,000
B. Nidd	320	14,000
Wharfe	492	13,000
Intervening areas	80	..
Population on river banks	..	33,000
C. Aire and Calder	815	676,000
D. Don	682	354,000
E. Derwent	794	17,000
Intervening areas	47	..
Population on river banks	..	2,000
Humber Basin.		
F. Ancholme	244	5,000
Hull river	394	137,000
Small catchments	595	..
Population on river banks	..	27,000

K.
TRIBUTARIES OF THE MERSEY.

Tributaries.	Area.	Population.
Goyt }	180	28,000
Etherow }		
Tame	60	81,000
Irwell	812	842,000
Bollin	112	59,000
Sanzey Brook	107	62,000
Weaver	515	51,000
Small catchments	448	
Population on river banks		101,000

L.

TRIBUTARIES OF THE RIBBLE.

Tributaries.	Area.	Population.
Upper Ribble	355	60,000
Hodder } Calder }	234	
Darwen	57	102,000
Douglas	172	62,000
Population on river banks	..	120,000
Intermediate drainage	62	
Wyre	208	2,000
Population on coast		4,000

M.

RIVER OF THE LAKE DISTRICT.

Tributaries.	Area.	Population.
A. Lune	418	26,000
Kent	255	16,000
Intervening coast		4,000
B. Leven	202	11,000
Dudden	46	1,000
Esk	64	
Irt	61	
Calder	28	
Ehen	72	2,000
Derwent	262	16,000
Ellen	72	
Waver	70	
Wampool	28	3,000
Small catchments	95	40,000
C. Eden	915	47,000
Liddel	104	2,000
Intervening area	21	

N.

RIVERS OF DURHAM AND NORTHUMBERLAND.

Tributaries.	Area.	Population
A. Esk	147	21,000
Tees	706	111,000
Coast Drainage	177	13,000
B. Wear	456	202,000
C. Tyne	1,130	364,000
D. Blyth	131	3,000
Wansbeck	126	7,000
Coquet	240	2,000
Aln	104	7,000
Till	231	2,000
Intervening coast	252	14,000

APPENDIX III.

NAMES AND POPULATIONS OF THE CITIES AND TOWNS WITHIN EACH RIVER BASIN OF ENGLAND AND WALES.

A.

NAMES OF TOWNS ON THE RIVER THAMES AND ITS CHIEF TRIBUTARIES, WITH THEIR POPULATION IN 1871.

(a.) Upper Basin.

Towns on the Thames.	Tributaries.	Town on tributaries.	Population.
	Churn	Cirencester	7,681
Cricklade	......	......	1,845
	Coln	Fairford	1,626
	Cole	Swindon	11,720
	,,	Highworth	1,900
	Leach Brook	North Leach	901
	,,	Southrop	1,070
Lechlade	......	......	1,272
	Bampton Brook	Faringdon	3,252
	Windrush	Burford	1,403
	,,	Witney	2,976
	Evenlode	Moreton-in-the-Marsh	1,468
	,,	Stow-on-the-Wold	1,373
	,,	Charlbury	1,335
	,, (Glyme)	Chipping Norton	3,611
	,, ,,	Woodstock	7,477
	Cherwell	Banbury	4,122
	,,	Deddington	1,540
	,, (Ray)	Bicester	3,018
Oxford	......	......	32,477
	Ock	Wantage	3,295
Abingdon	......	......	5,799
	Thame	Wendover	5,790
	,,	Aylesbury	6,962
	,, (Branch)	Princes Risboro'	2,549
	,,	Thame	2,843
	,,	Watlington	1,943
Wallingford	......	......	2,972
	Pang	East Ilsley	1,032

(b.) Middle Basin.

Towns on the Thames.	Tributaries.	Towns on tributaries.	Population.
Reading	......	......	32,324
	Kennet	Marlborough	6,879
	,,	Hungerford	4,343
	,,	Newbury	7,703
	,, (Lambourne)	Lambourne	1,180
	,, (Embourn)	King's Clere	2,781
	Loddon	Wokingham	2,868
Henley	......	......	4,523
Great Marlow	......	......	6,627
	Wick	High Wycombe	8,661
	,,	Beaconsfield	1,824
Maidenhead	......	......	6,173
Windsor	......	......	11,769
Eton	......	......	2,806
Slough	......	......	4,509
Datchet	......	......	990
Egham	......	......	5,995
	Colne	Berkhampstead	4,086
	,, (Gade)	Hemel Hempstead	5,996
	,,	King's Langley	1,496
	,,	Abbot's Langley	2,638
	,,	Watford	7,461
	,, (Ver)	St. Albans	8,298
	,, (Chess)	Chesham	2,244
	,,	Amersham	2,726
	,,	Rickmansworth	5,737
	,,	Uxbridge	7,497
	,,	Colnbrook	1,155
Staines	......	......	3,464

Middle Basin.—(*Continued.*)

Towns on the Thames.	Tributaries.	Towns on tributaries.	Population.
Chertsey	......	......	3,146
	Wey	Alton	4,092
	,,	Farnham	4,461
	,,	Godalming	2,444
	,,	Guildford	9,106
	,,	Woking	6,568
	,,	Weybridge	1,372
Shepperton	......	......	1,126
Walton	......	......	5,383
Sunbury	......	......	3,368
West Moulsey	......	......	563
	Mole	Bletchingley	1,916
	,,	Reigate	15,916
	,,	Dorking	5,419
	,,	Leatherhead	2,455
	,,	Cobham	2,133
	,,	East Moulsey	2,409
Hampton Wick	......	......	2,297
Esher	......	......	1,460
Thames Ditton	......	......	1,084
Surbiton	......	......	7,642
Kingston	......	......	15,263
	Hog's Mill	Epsom	6,276
	,,	Ewell	2,535
	,,	Maldon	5,586

(*c.*) *Lower Basin.*

Towns on the Thames.	Tributaries.	Towns on tributaries.	Population.
Ham	......	......	1,239
Twickenham	......	......	10,533
Richmond	......	......	15,113
Hounslow	......	......	9,294
Isleworth	......	......	11,498
Brentford	......	......	11,091
	Brent	Barnet	3,720
	,,	Finchley	7,146
	,,	Hendon	6,972
	,,	Edgeware	655
	,,	Harrow	4,997
	,,	Pinner	2,332
	,,	Hanwell	3,766
	,,	Ealing	9,959
Kew	......	......	1,033
Mortlake	......	......	5,119
Barnes	......	......	4,197
Chiswick	......	......	8,508
	(Branch)	Acton	8,306
Hammersmith	......	......	42,691
Putney	......	......	9,439
Fulham	......	......	23,350
Wandsworth	......	......	19,783
	Wandle	Carshalton	3,668
	,,	Croydon	55,652
	,,	Mitcham	6,498
	,,	Tooting	2,327
	,,	Streatham	12,148
	,,	Wimbledon	9,087
Battersea	......	......	67,218
London (North Bank)	......	......	3,188,219
London (South Bank)	......	......	713,057
Deptford	......	......	60,188
Greenwich	......	......	169,361
	Ravensbourn	Bromley	10,674
	,,	Lee	10,493
	,,	Eltham	4,539
	,,	Lewisham	36,525
	Lea	Dunstable	4,558
	,,	Luton	17,317
	,,	Hatfield	3,998
	,, (Beane)	Stevenage	2,909
	,, (Rib)	Buntingford	1,014
	,,	Hertford	7,169
	,,	Ware	4,917
	,, (Stort)	Bishop's Stortford	6,250
	,,	Hoddesdon	2,090
	,,	Broxbourne	2,872
	,,	Waltham Abbey	5,197
	,,	Epping	2,275

Lower Basin.—(*Continued.*)

Towns on the Thames.	Tributaries.	Towns on tributaries.	Population.
Woolwich	......	......	35,557
	Roding	Ongar	2,103
	,,	Wanstead	5,119
	,,	Barking	5,776
	Ingerburn	Romford	6,335
Erith	......	......	8,289
	Darent	Westerham	2,283
	,,	Sevenoaks	4,118
	,,	Wrotham	3,201
	,,	Farningham	854
	,,	Shoreham	3,678
	,,	Dartford	8,298
Purfleet	......	......	1,486
Greenhithe	......	......	1,452
Thurrock (Grays and West)	......	......	2,806
Tilbury	......	......	974
Gravesend	......	......	21,265
	Crouch	Billericay	1,451
	,,	Rayleigh	1,404
	,,	Rochford	1,589

B.

NAMES OF TOWNS ON THE RIVER BASINS AND THE COAST SOUTH OF THE THAMES BASIN, WITH THEIR POPULATIONS IN 1871.

Medway.

Tunbridge Wells	19,410
Eden—Bletchingly	1,916
Godstone	2,254
Edenbridge	1,891
East Grinstead	5,390
Tunbridge	15,378
Beult—Cranbrook	4,331
Maidstone	26,237
Rochester, Stroud, and Chatham	43,116
Sheerness	13,956
The Swale—Sittingbourne	6,418
Milton	3,463
Faversham	7,319
Whitstable	4,881

Herne Bay	5,703
Margate	11,995
Broadstairs	1,926
Ramsgate	14,640

Stour.

Ashford	8,458
Canterbury	20,962
Sandwich	3,060

Deal	8,009
Walmer	3,816
Dover	28,506
Folkstone	14,791
Sandgate	1,840
Hythe	3,383
Romney	1,129
Lydd	1,936

Rother.

Tenterden	3,669
Rye and Winchelsea	8,290
Battle	3,495

Hastings and St. Leonards	32,028

Ashburn.

Hailsham	2,429

Cuckmere.

Heathfield	2,044

Ouse.

Uckfield	2,041
Lewes	10,753
Newhaven	2,549

Rottingdean	1,544
Brighton and Hove	90,011

Adur.

West Grinstead	1,344
Cuckfield	4,420
Steyning	1,665
Shoreham	28,906

Worthing	7,413

Arun.

Horsham	7,831
Western Rother—Petersfield	1,587
„ Midhurst	6,753
„ Petworth	3,304
Arundel	2,956
Littlehampton	3,272

Bognor	2,811
Chichester	9,054
Havant	2,634
Portsmouth and Southsea	102,000
Gosport	7,366
Fareham	7,023

Tichfield River.

Tichfield	4,369

Hamble River.

Bishop's Waltham	2,618

Itchen River.

Alresford	2,204
Winchester	16,366
Twyford	1,442
Bishopstoke	1,579
Millbrook and Shirley	11,845
Southampton	53,741

Test or Anthon.

Basingstoke	5,574
Whitchurch	1,965
Andover	5,501
Romsey	5,681

Lymington River.

Lymington	5,356

Avon.

Devizes	6,839
Amesbury	1,169
Wiley—Warminster	5,786
„ Heytesbury	993
„ Wilton	8,865
Salisbury	13,839
Ludgershall	554
Downton	3,654
Cranbourne	2,562
Fordingbridge	3,053
Ringwood	3,781
Christchurch	15,415

Stour.

Stalbridge	2,096
Stourminster Newton	1,965
Blandford Forum	1,536
Wimborne Minster	5,019

C.

NAMES OF TOWNS ON THE COAST AND WITHIN THE RIVER BASINS OF THE SOUTH-WEST OF ENGLAND, WITH THEIR POPULATIONS IN 1871.

Poole	10,097

Frome.

Cernę Abbas	1,164
Bere Regis	1,676
Wareham	3,050
Dorchester	6,915

Corfe Castle	1,806

Wey.

Weymouth and Melcombe Regis	13,259

Brit.

Beaminster	2,585
Bridport	7,670

Lyme.

Lyme Regis	2,333

Ax.

Axminster	2,861
Colyton	2,479
Axmouth	702

Sid.

Sidmouth	3,360

Otter.

Honiton	3,464
Ottery St. Mary	4,110

Exe.

Bampton	1,926
Tiverton	10,024
Silverton	1,288
Collumpton	2,967
Bradninch or Braines	1,914
Crediton	5,778
Exeter	44,226
Topsham	3,121
Exmouth	5,614

Dawlish	4,241

Teign.

Moreton Hampstead	1,551
Chudleigh	2,042
Newton Abbott	2,194
Teignmouth	6,751

Torquay	21,657
Paignton	3,590
Brixham	6,542

Dart.

Ashburton	2,952
Totness	4,073
Dartmouth	5,338

Kingsbridge	1,557

Aulne.

South Brent	1,449

Erme.

Ermington	2,010
Modbury	1,751

Plym.

Plymouth	70,091
Plympton	1,084

Tavy.	
Tavistock	7,781
Tamer.	
Holsworthy	1,645
Launceston	2,935
Saltash	2,293
Devonport	64,074
St. German's River.	
Callington	2,173
St. German's	2,678
Looe.	
Liskeard	6,499
East and West Looe	2,194
Fowey.	
Lostwithiel	922
Fowey	1,394
St. Austell	3,803
Mevagissy	2,073
Fal.	
Tregony	745
Truro	3,069
Penryn	3,679
Falmouth	5,294
St. Mawes	1,003
Helston	3,797
Marazion	1,267
Penzance	10,414
St. Ives	6,965
Phillack	4,165
Camborne	7,757
Redruth	10,685
St. Michael's	1,000
St. Columb Major	1,113
New Quay	1,121
Camel.	
Camelford	1,250
Bodmin	4,672
Wadebridge	1,594
Padstow	1,991
Stratton	1,839
Hartland	1,871
Torridge.	
Hatherleigh	1,684
Okement—Oakhampton	1,900
Torrington	3,529
Bideford	6,969
Taw.	
Chumleigh	1,594
L. Dart—South Molton	3,978
Mole—North Molton	1,703
Barnstaple	11,659
Ilfracombe	4,721
Porlock	777
Minehead	1,665
Dunster	1,156
Crewkerne	3,557
South Petherton	2,065
Parret.	
Isle—Chard	2,400
„ Ilminster	2,431
Yeo—Yeovil	8,527
„ Ilchester	743
„ (*Branch*) Somerton	2,302
Langport	1,018
Tone.	
Wiveliscombe	2,059
Milverton	2,018
Wellington	5,199
Taunton	14,597
North Petherton	3,985
Bridgwater	3,539
Brue.	
Bruton	1,691
Castle Carey	2,021
Glastonbury	3,688
Shepton Mallet	4,163
Street	2,157
Ax.	
Wells	4,518
Axbridge	830

D.

NAMES OF TOWNS WITHIN THE BASIN OF THE SEVERN AND ITS TRIBUTARIES, WITH THEIR POPULATIONS IN 1871.

Upper Severn.	
Llanidloes	3,428
Newtown	4,874
Welshpool	4,033
Vyrnwy.	
Llanfilly	1,132
Llansaintfraid	1,362
Oswestry	7,036
Perry.	
Ellesmere	6,309
Shrewsbury	23,406
Tern.	
Whitchurch	3,696
Market Drayton	4,039
Mess—Newport	3,202
Roden—Wem	3,880
Wellington	5,926
Wenlock	19,401
Coalbrookdale	1,574
Ironbridge	3,605
Madeley	9,475
Broseley	4,639
Worf.	
Shifnal	2,190
Bridgnorth	5,320
Bewdley	3,021
Stour.	
Wolverhampton (part)	35,000
Dudley	43,782
Hale's Owen	2,984
Stourbridge	9,376
Kidderminster	19,473
Stourport	3,081
Salwarp.	
Bromsgrove	6,967
Droitwich	3,504
Worcester	33,326
Teme.	
Knighton	1,743
Clun—Clun	1,127
Ludlow	5,087
Tenbury	1,210
(*Branch*) Great Malvern	5,693
Upton-on-Severn	2,664
Tewksbury	5,409

Upper Avon.

Rugby	8,385
Sow—Coventry	37,670
„ Southam	1,785
Leam—Leamington	20,910
Warwick	10,986
Kington	2,126
Stratford	7,183
Stour—Chipping Camden	2,013
„ Shipston-on-Stour	1,800
Arrow—Henley in Arden	1,101
„ Alcester	2,363
Evesham	4,880
Pershore	2,826

Chelt.

Cheltenham	41,923

Gloucester	18,341

Stroud Water.

Minchinhampton	4,361
Stroud	7,082
Painswick	4,019

Westbury-on-Severn	2,495
Newnham	1,483

Small Branch.

Dursley	2,413

Small Branch.

Wickwar	902
Wotton-under-edge	2,314
Berkeley	1,161

Small Branch.

Thornbury	1,630

Wye.

Builth	1,059
Talgarth	1,408
Hay	2,011
Hereford	18,327
Lugg—Presteign	2,460
„ Radnor	1,870
„ Aymestry	775
„ Leominster	4,749
„ (*Branch*) Kington	2,126
„ „ Pembridge	1,535
„ „ Weobley	932
Frome—Bromyard	1,322
Ross	3,586
Monnow—Monmouth	5,879
Chepstow	3,347

Lower Avon.

Tetbury	3,449
Malmesbury	3,123
Wootton Bassett	2,392
Calne	3,333
Chippenham	3,936
Corsham	3,390
Melksham	2,464
Trowbridge	11,508
Bradford	4,877
Marshfield	1,788
Bath	32,557
Keynsham	2,240
Bristol	182,523
(*Branch*) Chipping Sodbury	1,157
Portishead	2,137

Usk.

Brecknock	5,845
Crickhowel	1,464
Abergavenny	4,803
Usk	1,616
Pontypool	4,834
Caerleon	1,306
Newport	9,844
Tredegar	12,389
Caerphilly	2,309

Taff.

Merthyr Tydvil	51,949
Llandaff	11,922
Cardiff	39,536

E.

NAMES OF TOWNS IN THE RIVER BASINS OF WALES, AND THEIR POPULATIONS IN 1871.

a. *Draining South.*

Ogmore—Bridgend	3,539
Afon—Aberafon	3,574
Neath—Neath	9,319
Tawe—Swansea	51,702
Llwchwr—Llanelly	15,281
„ —Lougher	1,280
Gwendraeth Vawr—Kidwelly	2,072
Towy—Llandovery	1,861
„ Llandeilo	1,470
„ Llangadoch	2,830
„ Carmarthen	10,488
Taf—Laugharne	1,742
East Cleddau—Narberth	1,266
West Cleddau—Haverford West	6,622

b. *Draining West.*

Teifi—Tregaron	1,788
„ Lampeter	1,225
„ Newcastle Emlyn	1,757
„ Cardigan	3,461
Ystwith *Rheidol* } —Aberystwith	6,898
Dovey—Dinas Mawddy	797
„ Machynleth	2,042
Maddach—Dolgelly	2,357
Seiont—Carnarvon	9,449

c. *Draining North.*

Conway—Llanrwst	3,767
„ Conway	2,620
Clwydd—Ruthin	3,298
„ Denbigh	6,323
„ St. Asaph	1,900
„ Rhyddlan	1,233
„ Rhyl	4,229
Dee—Bala	1,539
„ Corwen	2,646
„ Llangollen	2,798
„ Ruabon	15,150
„ Chirk	1,919
„ Malpas	962
„ Wrexham	8,576
„ Holt	1,056
„ Mold	3,978
„ Hawarden	6,782
„ Chester	35,257
„ Flint	4,269
„ Neston and Parkgate	2,838
„ Holywell	3,540

URBAN POPULATION ON THE COAST.

a	Tenby	3,810
	Pembroke	13,704
	Wilford	3,252
b	St. David's	1,000
	Fishguard	1,581
	Cricueth	812
	Pwlhelli	3,009
	Nevin	1,791
c	Bangor	9,850
	Llandudno	2,762
	Abergele	3,194

F.

Names of Towns in the River Basins of Rivers Flowing into the Wash, and those of the Adjoining Lincolnshire Coast.

Great Ouse.

Brackley	2,351
Buckingham	3,703
Winslow	1,826
Stony Stratford	1,976
Wolverton	2,804
Tove—Towcester	2,465
Newport Pagnell	3,655
Ouzel—Tring	4,045
„ Ivinghoe	1,722
„ Woburn	1,605
„ Leighton Buzzard	4,696
„ Fenny Stratford	1,590
Olney	2,547
Harrold	1,042
Bedford	16,850
Ivel—Ampthill	2,220
„ Shelford	1,111
„ (*Hiz*) Hitchin	7,630
„ Baldock	2,036
„ Biggleswade	4,244
„ Potton	2,072
St. Neots	3,200
Kym—Kimbolton	1,509
Huntingdon	4,243
Godmanchester	2,363
St. Ives	3,291
Swavesey	1,335
Cam—Royston	1,801
„ Saffron Walden	5,718
„ Linton	1,838
„ Cambridge	30,078
Ely	6,114
Lark—Mildenhall	3,862
Little Ouse—Thetford	4,166
„ Brandon	2,216
Wissey—Walton	1,388
„ Swaffham	3,700
„ Stoke Ferry	706
Downham Market	2,752
Nar—Litcham	854
King's Lynn	17,266

Nen.

Daventry	4,051
Northampton	41,168
Wellingborough	9,385
Rothwell	2,448
Kettering	7,184
Higham Ferrars	1,232
Thrapston	1,223
Oundle	2,829
Kingscliffe	1,259
Peterborough	11,264
Saxby	1,393
Whittlesea	4,297
March	5,854
Wisbeach	9,362
Sutton St. Mary	4,253

Welland.

Market Harborough	2,362
Uppingham	2,464
Stamford	7,846
Guash—Oakham	2,911
Market Deeping	4,553
Crowland	2,459
Spalding	9,111
Glen—Grantham	5,028
„ Bourn	3,098
„ Donington	1,753
Glen—Swineshead	1,919
„ Holbeach	5,332

Witham.

Lincoln	26,766
Bain—Horncastle	4,865
Sleaford R.—Sleaford	3,592
Bolingbroke	947
Boston	14,526

Steeping River.

Spilsby	1,623
Wainfleet	1,355

Lincolnshire Coast.

Burgh	1,236
Alford	2,881
Ludd—Louth	10,500

G.

Names of Towns in the River Basins of the Eastern Counties, with their Populations in 1871.

Chelmer.

Thaxted	2,188
Dunmow	2,983
Chelmsford	9,318

Blackwater.

Braintree	4,790
Coggeshall	2,916
Witham	3,347
Maldon	5,586

Colne.

Halstead	5,783
Colchester	26,343

Stour.

Haverhill	3,031
Clare	1,887
Lavenham	1,886
Sudbury	6,908
Neyland	980
Bildeston	808
Bret—Hadleigh	3,575
Manningtree	970
Harwich	6,079

Gipping or Orwell.

Stow Market	4,097
Needham Market	1,393
Ipswich	42,947

Deben.

Debenham	1,349
Wickham Market	1,541
Woodbridge	4,403

Alde.

Framlingham	2,569
Saxmundham	1,292
Aldeburgh	1,990
Orford	1,022

Blythe.

Halesworth	2,437
Southwold	2,155

Waveney.

Diss	3,851
Eye	2,396
Harlston	1,662
Bungay	3,503
Beccles	4,844
Lowestoft	15,246

Wensum (Yare).	
Fakenham	1,831
East Dereham	3,689
Norwich	80,386
Wymondham	2,150
Yarmouth	41,819
Bure.	
Aylsham	2,346
North Walsham	2,842
Worstead	746

TOWNS ON THE NORFOLK COAST.

Cromer	1,423
Holt	1,563
Wells	3,044
Walsingham	1,509
Burnham Westgate	1,585

H.

NAMES OF TOWNS WITHIN THE BASIN OF THE TRENT, WITH THEIR POPULATION IN 1871.

Burslem	25,562
Hanley	18,407
Stoke-on-Trent	15,300
Lyme.	
Newcastle-under-Lyme	15,948
Longton and Lane-end	19,748
Stone	3,732
Sow.	
Eccleshall	1,484
Stafford	12,212
Penk—Brewood	3,237
„ Cannock	6,350
„ Penkridge	2,435
Rugeley	3,375
Blythe.	
Abbotts Bromley	1,456
Tame.	
Wolverhampton (part)	34,000
Wednesfield	9,000
Walsall	40,301
Wednesbury	116,809
Birmingham	343,787
Blythe—Coleshill	5,396
Anker—Nuneaton	7,399
„ Hinkley	6,902
„ Atherton	3,677
„ *Sence*—Market Bosworth	949
Tamworth	11,493
Lichfield	7,347
Mease—Ashby-de-la-Zouch	7,302
Burton-on-Trent	20,378
Dove.	
Hartington	2,966
Ashbourne	5,310
Rocester	1,341
Churnet—Leek	11,331
Tean—Cheadle	2,929
Uttoxeter	3,604
Tutbury	2,149
Castle Donnington	2,154
Derwent.	
Castleton	1,030
Hatherseage	1,021
Eyam	2,130
Wye—Buxton	3,717
„ Tideswell	1,915
„ Ashford	713
„ Bakewell	2,283
Darley	1,557
Winster	814
Matlock	5,220
Crompton	1,074
Bonsall	1,246
Wirksworth	3,338
Amber—Alfreton	3,680
Heage	2,195
Belper	8,527
Derby	49,810
Soar.	
Leicester	95,220
Wreak—Melton Mowbray	5,011
„ Syston	1,877
Mount Sorrel	1,995
Barrow	5,857
Loughborough	11,588
Kegworth	1,834
Erewash.	
Codner	3,689
Heanor	4,888
Lean.	
Hucknall Torkard	4,257
Nottingham	86,621
Devon.	
Bingham	1,629
Greet.	
Southwell	2,400
Newark	12,195
Small branch.	
Tuxford	1,016
Gainsborough	7,564
Idle.	
Mansfield	11,824
Maund—Ollerton	831
„ East Retford	3,194
Ryton—Worksop	1,486
„ Blythe	2,294
„ Bawtry	930
Epworth	2,295

I.

NAMES OF TOWNS ON THE BASINS OF THE OUSE AND HUMBER, WITH THEIR URBAN POPULATIONS IN 1871.

OUSE.

Swale.	
Muker	913
Reeth	1,077
Richmond	2,520
Northallerton	2,663
(*Branch*) Bedale	1,036
Thirsk	3,040
Ure.	
Hawes	1,843
Askrigg	607
Leyburn	887
Middleham	909
Masham	1,062
Ripon	6,806
Boroughbridge	857
Kyle.	
Easingwold	2,153
Nidd.	
Pateley-bridge	800
Ripley	1,334
Knaresborough	5,205
Harrogate	6,843
York	50,765

Wharfe.

Ilkley	2,511
Otley	5,855
Wetherby	1,657
Tadcaster	2,443

Cawood	1,179
Selby	6,193

Aire.

Gargrave	1,291
Skipton	6,042
Keighley	19,775
Bingley	15,952
Bradford Beck—Bradford	64,440
Bramley	9,882
Horsforth	5,465
Headingley	13,942
Leeds	259,212
Calder—Holme	724
" Hebden-bridge	3,894
" Sowerby-bridge	7,041
" Sowerby and Luddenden Foot	9,211
" Halifax	65,510
" Elland	6,432
" Brighouse	6,370
" Rastrick	5,846
" *Holme*—Holmfirth	5,613
" " Honley	4,906
" " Meltham	4,229
" " Huddersfield	70,253
" Dewsbury	24,764
" Heaton	1,929
" Horbury	3,977
" Wakefield	28,069
" Normanton	3,448
" Methley	3,277
Ferrybridge	920
Pontefract	5,350
Knottingley	4,039
Snaith	14,644

Howden	2,315

Derwent.

Pickering	3,689
Malton (New and Old)	5,000
Helmsley	1,437
Kirkby Moorside	1,788
Pocklington	2,622
Market Weighton	2,354

Don.

Penistone	1,549
Sheffield	239,916
Attercliffe	16,574
Rother—Chesterfield	11,427
" Dronfield	2,475
" Staveley	2,441
" Tinsley	953
" Rotherham	25,892
Dearne—Barnsley	23,021
" Darfield	1,673
" Wath	2.023
Doncaster	18,768
Tickhill	1.844
Thorne	2,618
Crowle	3,122

HUMBER.

Ancholme or *New River*—Market Rasen	1,100
" Caistor	2,012
" Glandford Bridge	1,692
Barton-on-Humber	4,332
Hull River—Driffield	5,067
" Beverley	10,218
" Hull	121,892
Hedon	900
Patrington	1,571
Grimsby	20,244

COAST TOWNS ADJACENT.

Scarborough	22,391
Filey	2,267

K.

NAMES OF TOWNS WITHIN THE BASIN OF THE MERSEY, AND THEIR POPULATIONS IN 1871.

Goyt—Chapel-en-le-Frith	3,715
Etherow—Mottram	2,590
" Glossop	17,046
" Marple	4,100
Stockport	53,014
Tame—Staleybridge	21,092
" Dukinfield	14,085
" Ashton-under-Lyme	31,984
" Hyde	14,223
Cheadle	2,929

Irwell.

Haslingden	7,698
Bacup	7,199
Bury	38,596
Roch—Rochdale	63,485
" Heywood	21,248
Tange—Bolton-le-Moors	82,853
Salford	124,801
Manchester	356,626
Irk—Middleton	14.517
Medlock—Oldham	82,629
" Altrincham	8,478
Glazebrook—Leigh	33,592

Bollin.

Macclesfield	35,450
Bollington	3,668
Wilmslow	7,861
Birkin—Knutsford	3,597
Sowbrook—Lymm	4,541

Warrington	32,140

Sankey.

St. Helen's	45,124
Prescot	5,990
Ashton-in-Makersfield	7,463
Newton-in-Makersfield	8,244

Runcorn	12,443

Weaver.

Nantwich	6,673
Whitchurch	3,696
Crewe	17,810
Northwich	2,894
Dane—Congleton	11,344
" Middlewich	3,085
" *Wheelock*—Sandbach	5,259
Frodsham	2,095

Branch—Tarporley	1,243

Wallasey	14,819
Wavertree	7,810
Liverpool	493,005
Bebington	6,940
Birkenhead	45,418
West Derby	27,292

L.

NAMES OF TOWNS WITHIN THE DRAINAGE AREA INCLUDING THE RIBBLE AND THE WYRE, WITH THEIR POPULATIONS IN 1871.

Ribble.

Settle	2,163
Gisburn	1,997
Clitheroe	8,208

Burnley	40,857
Padiham	6,675
Whalley	747
(*Branch*) Accrington	21,788
Darwen—Blackburn	76,339
,, Over and Under Darwen	25,154
Walton-le-Dale	8,187
Preston	85,427
Yarrow—Chorley	16,864
Douglas—Wigan	39,110
,, Ormskirk	6,127
Kirkham	3,593

Wyre.

Garstang	687
Poulton-le-Fylde	1,161
Fleetwood	4,428

M.

NAMES OF THE TOWNS IN THE VARIOUS RIVER BASINS OF THE LAKE DISTRICT, AND THEIR POPULATIONS IN 1871.

Lune.

Ravenstonedale	973
Orton	1,499
Sedbergh	1,983
Kirkby Lonsdale	1,766
Bentham (High and Low)	2,237
Bolton-le-Sands	753
Lancaster	17,245

Poulton by the Sands	3,005
Carnforth	1,091

Kent.

Kendal	13,446
Milnthorp	1,599
Barton in Kendal	679

Leven.

Ambleside	1,988
Hawkshead	1,085
Ulverstone	7,607

Duddon.

Broughton-in-Furness	1,085
Dalton-in-Furness	9,310

Ravenglass	602

Ehen.

Egremont	2,377

Whitehaven	18,451

Derwent.

Keswick	2,777
Cockermouth	5,115
Workington	7,979

Maryport	7,443
Allonby	572

Wampool.

Wigton	3,425

Eden.

Kirkby Stephen	1,871
Brough	669
Appleby	1,989
Penrith	8,317
(*Branch*) Brampton	2,617
Carlisle	31,049

Liddel.

Longtown	1,946

N.

NAMES OF THE TOWNS ON THE RIVER BASINS OF DURHAM AND NORTHUMBERLAND, WITH THEIR POPULATIONS IN 1871.

Esk.

Egton	1,330
Whitby	12,460

Guisborough .. .. .. : ..	6,202
Redcar	

Tees.

Middleton-in-Teesdale	2,386
Barnard Castle	4,306
(*Branch*) Staindrop	1,234
Skerne—Darlington	27,729
Yarm	1,340
Stockton	27,738
Middlesborough	39,563
Leven—Stokesley	1,877

Hartlepool	13,166
Seaham	2,802

Wear.

Stanhope	3,256
Wolsingham	7,778
Bishop Auckland	8,736
Durham	14,406
Chester-le-Street	2,450
(*Branch*) Hetton-le-Hole	7,935
Bishop Wearmouth	59,032
Sunderland .. .. .. : ..	98,242

Tyne.

South Tyne—Alston	2,627
,, Haltwhistle	1,668
,, *Allen*—Allendale	5,357
North Tyne—Bellingham	833

Tyne.

Hexham	5,331
Derwent—Newbiggen	1,137
Elswick	27,801
Wallsend	4,169
Newcastle	137,665
Gateshead	48,627
Walker	8,888
Jarrow	18,179
Heworth	13,756
Howden	1,112
South Shields	45,336
Tynemouth and North Shields	38,841

Blyth.

Blyth	2,918

Wansbeck.

Morpeth	5,914
Seaton	1,590

Coquel.

Rothbury	1,074
Warkworth	765

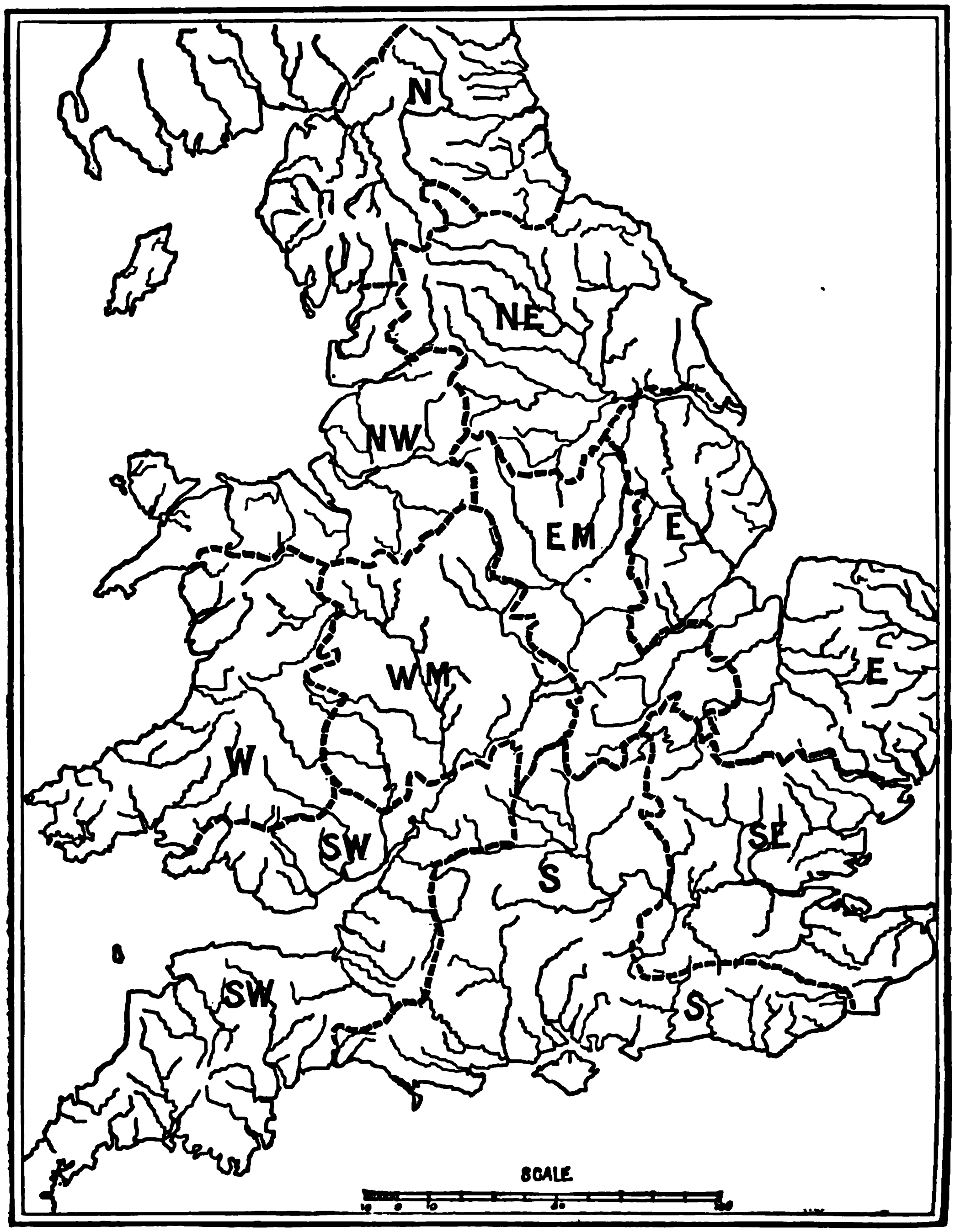
Alne.

Alnwick	6,218
Alnmouth	469

Till.

Wooler	1,610

Belford	1,020
Berwick-on-Tweed	13,282



MAP OF DISTRICTS PROPOSED BY SAMUEL B. GOSLIN.

ESSAY BY SAMUEL B. GOSLIN.

MOTTO.

'The princes digged the wells by the direction of the lawgiver."

THE SUBJECT.

It is hardly necessary to say that, in whatever light the problem is viewed, it is seen to be as vast in its magnitude as it is in its importance to the well-being of every individual in particular, or to the nation at large, not only for the present time but for generations to come. Recent legislation having to an extent laid out the ground for operations to be commenced, it remains—

(1.) To take an account of the requirements and conditions.

(2.) To consider the best and most available resources and materials for the work.

(3.) To divide the country, or to delineate the plans for operation.

(4.) To have the works carried out.

(5.) To provide the money for payment.

Withal taking the experiences of the past, and the collected evidence already given, as the guide to the final determination upon every proposal or point connected with the subject.

PROPOSALS.—REQUIREMENTS, &C.

The requirements or conditions of a water supply is always the first question put by the hydraulic engineer, whenever consulted, both as to the present and future periods, whether it be for city, town, village, mansion, farm, or factory; if it be for the nation, the same particulars or statistics are absolutely necessary. The particulars have been, to a very large extent, already compiled and supplied, but are not so complete in all their details as it is desirable that they should be.

It is to be seen that there are 25,349 various and separate places in England and Wales to be supplied with potable or "pure and wholesome" water in varied quantities, these places being comprised in 2,061 unions, 4,158 townships, 9,694 parishes, 470 hamlets, 102 chapelries, 151 tythings, with some few municipal boroughs, villages, liberties and precincts, covering an area of 53,320 square miles, with a population, in 1861, of 20,066,224; in 1871, 22,712,266; now about 25,000,000, with some 14,000,000 dwelling in towns and urban districts, and 11,000,000 dwelling in rural districts, villages, and small towns.

The population in the metropolis and urban districts is increasing rapidly, and that of the rural districts slowly, as was shown in 1871, to be in the proportion of 1·73 for the urban, against 0·71 in the rural districts. The population of necessity existing in two distinct classes, viz., (1) those closely packed in large towns and cities, easily served; (2) those dwelling in country parishes, villages, mansions, farms, &c., for the most part widely separated—as for instance (1) St. Pancras Union, Middlesex (one parish) with a population of 221,465, in 2,672 acres; (2) Staines Union, of 13 parishes, 20,199, in 24,332 acres; Aysgarth, Yorks, Union, of 12 parishes, 5,473, in 81,012 acres.

The present requirements, so far as quantity is concerned, may be easily computed, and the increase upon that quantity, which will be necessary in 60 or 70 years hence, may be gathered from the census tables, or the averages may be fairly set down as 12½ per cent. increase for every period of 10 years, so that as, in round numbers, the population to be supplied in 1871 was 22,700,000, in 1881 will be 24,500,000, in 1891 will be 28,700,000, in 1901 will be 32,300,000, in 1911 will be 36,300,000, in 1921 will be 30,900,000, in 1931 will be 46,000,000, in 1941 will be 51,700,000, and taking 20 gallons per diem per head, shows a quantity of 454,000,000 gallons needed in 1871, 511,000,000 gallons needed in 1881, 1,035,000,000 gallons needed in 1941, to be distributed in exceedingly diversified conditions of levels.

The second question put by the hydraulic engineer is "What are the levels?" or, in other words, from what depth and to what height is the water to be raised, from what level is it to gravitate, or from what fall will the power to raise it be given? and to this the complete answer cannot at present be given; the Ordnance Survey will eventually serve the purpose when it has been completed; and the writer ventures the suggestion that this is a matter of primary importance. The Ordnance Survey should be completed without a day's delay.

It then follows, as being very necessary, that a full inquiry should be made, and the reports fully recorded of all the existing conditions of every place in the country, the depths and water levels in all the wells, the size and analysis of all the streams, &c.; but this can only be done by an appointed Board or Commission, acting in various departments, if it is to be accomplished in a reasonable time. It has been shown in part by the Rivers Pollution Commissioners reports, and by the reports of other inquiries, as well as being fully realised after a few visits in various parts of the country, that the conditions are as diverse as it is possible to find them.

In many cases, in rural districts, there is a supply of water at the feet of the people, only needing some simple machinery to lift it; in other cases, difficult to be found anywhere near, either in wells or streams, of a pure and wholesome character. In some cases, the people are hindered, by incompetent water companies or selfish landowners, from obtaining the available supply; in others, the people being supplied by exacting and wealthy corporations; in some cases, the people using and drinking sewage impurities from ponds, tanks, and streams, as the only available source and supply; in others, the purest water being supplied from deep-seated springs, by local authorities, borough corporations, and smaller public companies.

It cannot be worth while to upset an existing arrangement, if it be found to be adequate and sufficient for a prospective increase of population in its mechanical arrangements, even if it is considered to be advisable to have it placed more directly under Government supervision, which every water supply should be, as a decidedly "national question."

The best and the most available resources have received considerable attention, as the rainfall, the rivers, the lakes, the wells, the streams, but not sufficient for this question, as the record will show at a glance, taking those of the rainfall from the 2,000 stations in existence. They do not by any means give accurate and trustworthy data of the 25,349 places in the country. It is not sufficient to map out and mark off certain spaces of average without stations of record, as in the east part of the Tendring Hundred district in Essex, where it is placed and averaged at the same rate as between Romford and Colchester in the same county. It is proverbial that the former has but little rain compared with the latter, as when at the latter a comparatively continuous rainfall was experienced for six weeks, two small showers were the portion of the former.

It is seen that the rivers and streams are for the most part polluted; that the wells contain, in some cases, brackish water; but in most cases where deep or artesian, there is a bountiful supply of pure water, irrespective of particular district rainfall, much as it is in other countries, as India, Africa, New Zealand, &c. The lakes offer an abundant water supply, fed by rains which have been measured to some extent, and, mists which, although of more frequent occurrence, few records, and little notice have been taken, nevertheless they form an important factor in the question of water supply.

The velocity or pressure of the wind, another factor of great importance in connection with water supply in urban and rural districts, has never been recorded throughout the country.

The geological statistics and records serve well as a basis to start upon in connection with a hydro-geological survey; a work absolutely essential for the determination of the question of "National Water Supply," the geological records serving as an indication of the qualities of the waters in some particulars, but often insufficient, as in the chalk underlying clay pure water may be found at Thorpe-le-Soken and at Walton-le-Soken, four miles only distant from Thorpe, the water from the same strata is brackish, and useless for the purpose desired. So is it in many other cases.

The hydraulic engineer naturally inquires as to the available resources before he can draw the lines of his plan, or give his decision or advice for a water supply. And, considering that, in connection with the question of the National Water Supply, the magnitude and variety of the requirements, the diversity of the conditions, the imperfect knowledge of the available local resources, the incomplete data of the geometrical, geological, and meteorological aspects of the country (the most complete information being necessary), these must influence the divisions of the country which may be desirable at the present time.

Everything points to the fact that, wherever the divisions are made, or the lines drawn, they can now only represent the parts of a scheme, which may ultimately be improved in the final arrangement. This is clear, and can be decided at once—that no one scheme or arrangement will be found to be suited to every place, or group of places.

To effect a satisfactory result, the country should be divided into parts, or departments, and subdivided into districts, as they are termed in France, each department being under the control and study of various officers of a "National Hydraulic Board," or "Board of Public Works," whose duty it should be at once to collect the necessary data of every district in their department, as per Form A, their departments, or divisions, being those of the rivers, as in France, or, for the immediate purpose, as per Map and Table A, or Key B, which divisions include a series of complete counties.

There are many advantages arising out of this plan of division, inasmuch as that the counties are already divided into urban and rural districts, with their respective authorities, all the statistics gathered of population, acreage, rateable value, collectors, and places of meeting, having every facility for the collection of funds for the work required, and the supervision of the works when determined upon. It is the fact that, in most, if not in every case where there is no good supply at the present time, the evil has continued, more from the want of a decision as to what should be done, than from inability to find the money or the workmen to carry out the work, there being self-interests, diversities of opinion, and the fear of not doing the best, or spending money of the ratepayers badly, which have hindered progress in public works in urban and rural districts.

The decision of the department of the National Hydraulic Board being given as to what is to be done, and the law made that it must be done or carried out, is what is needed at the present juncture.

It would be an easy matter for the engineering branch of the National Hydraulic Board to decide the question what is to be done in each district, in a group of districts, or in the department, when the statistics are taken as enumerated, whether the supply should be from lakes, wells, or streams, or whether the distribution should be effected by gravitation, by water power, by wind power, or by steam power; each having their special advantages under certain conditions.

For the payment of the outlay and maintenance, the easiest and best plan is to take the existing Unions or districts in departments, as shown where the Poor-law Act is in force and rural sanitary authorities exist; for the assessment several plans may be suggested.

1. Let the cost be charged upon the land, as the landowners must reap the benefit of improved property more suited for human habitation.
2. Let every ratepayer, upon the usual assessment of the poor's rate, pay his part of a consolidated national water supply rate, so that the wealthy help the poor, the strong help the weak.
3. Let every male be taxed upon a return of income or wage, the return being collected at the time of the census, so that the working man or mechanic may pay his proportions as well as the poor clerk, the landowner, or nobleman. For all this there must of necessity be an Act of the law-givers; they must strike the rocks of hard places, ideas, and circumstances.

1. To appoint the permanent National Hydraulic Board to deal with the National Water Supply and sewage disposal.
2. To sanction or appoint the lines or boundaries of the departments and districts.
3. To give power to that Board to consider and decide what is best, and to be done in each and all cases.
4. To appoint the means, so that the decisions shall be put into operation by rural or sanitary authorities, or the Public Works Department.
5. To appoint the officers for the permanent inspection and maintenance of the National Works.[*]

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[*] For staff and departments of the staff of the National Hydraulic Board see D. form.

6. To decide upon the place of assessing for the funds required.

7. To decide upon the means of collection, that all may be paid.

SUMMARY OF SUGGESTIONS.

A. To take a full account of the requirements and condition of the peoples.

B. To take an account and to consider the best and most available resources for the work.

C. To draw out the plan of division and of district and department works.

D. To carry out the work.

E. To appoint means for payment.

F. The statistics and particulars to be taken for every place—as for a single place now—this is absolutely necessary.

G. The present statistics are not sufficient, being too general.

H. The requirements should be anticipated for 60 or 70 years.

I. The Ordnance Survey should be completed without delay.

J. A National Hydraulic Board should be appointed.

K. Every water supply should be under Government inspection or supervision and control.

L. Mist-fall and wind-pressure records should be taken.

M. Whatever divisions are now made, they will have to be modified as parts of a whole scheme.

N. No one arrangement will be found suited to every condition.

O. The country should be divided into departments and districts.

P. The departments may be as Map, and Form B.

Q. The department Board to decide what is to be done.

R. A law must be made to give powers.

S. Sketches of requirements to be embodied in Bill.

TABLE A.

NATIONAL WATER SUPPLY.

Departments.	Counties included.	Acreage.	Population.	Rateable Value.	Rainfall Average.
				£	
NORTH........	Northumberland	1,290,312	386,646	172,578	25 to 70 inches.
	Cumberland	970,161	220,253	97,295	
	Westmoreland	500,906	65,010	26,168	
	Durham	647,592	685,089	283,741	
		3,408,971	1,356,998	£579,782	
NORTH EAST ..	Yorkshire:—E. Riding.	750,828	268,466	153,174	25 to 30 inches.
	N. Riding.	1,361,664	293,278	135,478	
	W. Riding.	1,790,359	1,874,611	761,374	
		3,902,851	2,436,355	£1,050,026	
NORTH WEST..	Lancashire............	1,207,926	2,819,495	1,410,698	40 to 50 inches.
	Cheshire	705,493	561,201	260,459	30 to 50 inches.
	Denbighshire..........	392,005	105,102	Wales not divided	25 to 75 inches.
	Carnarvonshire	369,482	106,121		
	Anglesey	193,511	51,040		
	Flintshire	169,662	76,312		
		3,038,079	3,719,271		
EAST	Lincolnshire	1,767,962	436,599	237,591	under 25 inches.
	Rutland	94,889	22,073	14,415	
	Norfolk..............	1,356,173	438,658	269,351	
	Suffolk	949,825	348,869	199,425	
		4,168,849	1,246,197	£720,782	

Departments.	Counties included.	Acreage.	Population.	Rateable value.	Rainfall Average.
EAST MIDLAND .	Derbyshire	656,243	379,394	134,824	25 to 40 inches.
	Nottinghamshire	526,176	319,758	191,303	
	Leicestershire	511,719	269,311	179,634	
	Northamptonshire	629,912	243,891	192,028	
	Huntingdonshire	229,515	63,708	44,866	
	Cambridgeshire........	524,926	186,906	138,113	
		3,678,491	1,462,968	£880,318	
WEST	Merionethshire	385,291	46,598	Wales not divided	40 to 75 inches.
	Montgomeryshire	485,351	67,263		
	Cardiganshire	443,387	73,441		
	Radnorshire	276,552	25,430		
	Pembrokeshire	393,682	91,998		
	Carnarthenshire	606,172	115,710		
	Brecknockshire	460,158	59,901		
		3,050,593	580,341		
WEST MIDLAND	Staffordshire	732,434	858,326	331,466	25 to 30 inches.
	Shropshire	841,167	248,111	137,630	
	Warwickshire	566,458	634,189	308,577	
	Worcestershire	472,453	338,837	174,331	
	Herefordshire	532,898	125,370	116,425	
		3,145,410	2,204,833	£1,068,429	
SOUTH EAST .. * Part 1	Bedfordshire	295,509	146,257	111,413	25 to 30 inches.
	Hertfordshire	319,141	192,226	140,255	
	Essex	1,055,133	466,436	318,887	
		1,741,783	804,919	..	
* Part 2	Middlesex	181,317	2,539,265	2,030,627	
	Surrey	483,178	1,091,365	723,477	
	Kent	1,004,984	848,294	610,560	
		1,669,479	4,478,924	£3,935,221	
SOUTH .... * Part 1	Oxford	470,095	177,975	130,789	25 to 40 inches.
	Buckinghamshire	467,009	175,879	40,697	
	Berkshire	450,132	196,475	167,188	
	Wiltshire	859,303	257,177	196,484	
* Part 2	Hampshire............	1,032,105	544,684	320,692	
	Dorset................	627,265	195,357	135,278	
	Sussex................	934,006	417,456	298,943	
		4,839,915	1,964,603	£1,340,271	
SOUTH WEST ..	Glamorganshire	547,070	397,859	Wales not divided.	25 to 75 inches.
	Monmouthshire	368,399	195,448	116,008	
	Gloucestershire	804,997	534,640	293,501	
	Somersetshire	1,049,815	463,483	330,017	
	Devonshire............	1,655,161	601,374	342,222	
	Cornwall..............	869,878	362,343	169,764	
		5,295,300	2,555,147		

GEOLOGY.—(See Table D.)—Mr. Best says:—"The geological survey of England and Wales is not in a complete state, and the maps generally do no more than show the strata directly under the top soil. The description of the geology of the counties of England and Wales has never yet been compiled. W. J. Harrison, Esq., of the Town Museum, Leicester, has the work in hand for Messrs. Kelly; he has finished, and that of 25 counties has been published. W. J. H. is "in hopes" of finishing his work this year, which will be exceedingly useful. It is highly necessary not only to take the geology of every county, but of every place, with the water-bearing strata, as has been said by Mr. Best, 'because in chalk you get water in one place, it does not follow that you will in another.'"

NOTE.—The average acreage of departments is from 3 000,060 to 5,000,000.

* It may be advisable to divide S.E. and S. departments into two parts; total acreage or S.E., 3,411,262; population, 5,[illegible].

PLACE. TABLE B. COUNTY.

Department.	District.	Population.	Ratio of Increase.	Acreage.	Dwellings—Number of.	Present Water Supply, if any—Description of, with Analysis.	Rainfall and Mist—Average of.	Wells existing—Description of, with Depths, and Strata passed.	Lakes and Streams—Description of.	Levels—Ordnance Datum.	Geological Formation of Water-bearing Strata.	Wind Pressure or Velocity.	Waterfalls—Description of, Height, Quantity.	Adjoining or Next District—Name and Distance of.	General Remarks.
DECISIONS.		QUANTITY REQUIRED.				BEST SUPPLY AVAILABLE.				POWER TO BE UTILISED.					

Departmental Geology of England and Wales.]

TABLE C.*

[*To accompany Map.*

		TERTIARY, OR CAINOZOIC.																		
DEPARTMENT.	COUNTIES.	POST TERTIARY.				EOCENE.										CRETACEOUS				
		Post pliocene.		Pliocene.		Upper.				Middle.		Lower.				Upper.			Lower.	
		Post glacial.	Glacial.	Red crag.	Coralline crag.	Bembridge beds.	Headon beds.	St. Helen's beds.	Osborne beds.	Barton beds.	Bagshot beds.	London clay.	Woolwich beds.	Reading beds.	Thanet sands.	Chalk.	Greensand.	Gault.	Neocomian.	Wealden.
N.	Northumberland																			
	Cumberland																			
	Westmoreland																			
	Durham																			
N.E.	Yorkshire :—E. Riding		+													+	+		+	
	N. Riding																			
	W. Riding																			
N.W.	Lancashire																			
	Cheshire	+																		
	Denbighshire																			
	Carnarvonshire	+																		
	Anglesey																			
	Flintshire																			
E.	Lincolnshire															+	+		+	
	Rutlandshire																			
	Norfolk		+	+												+	+			
	Suffolk		+	+	+										+	+				
E.M.	Derbyshire																			
	Nottinghamshire																			
	Leicestershire																			
	Northamptonshire																			
	Huntingdonshire																+			
	Cambridgeshire																+	+		
W.	Merionethshire																			
	Montgomeryshire																			
	Cardiganshire																			
	Radnorshire																			
	Pembrokeshire																			
	Carmarthenshire																			
	Brecknockshire																			

		SECONDARY, OR MESOZOIC.																			
DEPARTMENT.	COUNTIES.	JURASSIC.													TRIASSIC.			PERMIAN.			
		Upper oolites.			Middle oolites.		Lower oolites.					Liassic.						Upper.	Middle.	Lower.	
		Purbeck.	Portland beds.	Kimmeridge clay.	Coral rag.	Oxford clay.	Cornbrash marble.	Forest marble.	Great oolite.	Inferior oolite.	Middle oolite.	Upper lias.	Lower lias.	Avicula contorta beds.	Keuper beds.	Muschelkalk beds.	Bunter.	Magnesian limestone.	Marls.	Sandstones.	Coal measures.
N.	Northumberland																				+
	Cumberland																	+	+	+	+
	Westmoreland																		+	+	+
	Durham																	+	+	+	+
N.E.	Yorkshire :—E. Riding			+																	
	N. Riding				+					+		+						+			
	W. Riding									+								+			+
N.W.	Lancashire														+		+			+	+
	Cheshire														+		+			+	+
	Denbighshire																				+
	Carnarvonshire																				
	Anglesey																				
	Flintshire																				+
E.	Lincolnshire			+																	
	Rutlandshire						+					+	+								
	Norfolk																				
	Suffolk																				
E.M.	Derbyshire														+		+		+	+	+
	Nottinghamshire												+	+	+			+	+	+	+
	Leicestershire												+		+		+			+	+
	Northamptonshire					+	+		+	+		+	+								
	Huntingdonshire				+	+	+		+	+										+	
	Cambridgeshire																				
W.	Merionethshire																				
	Montgomeryshire																				
	Cardiganshire																				
	Radnorshire																				
	Pembrokeshire																				
	Carmarthenshire																				
	Brecknockshire																				

		PRIMARY, OR PALÆOZOIC.																						
DEPARTMENT.	COUNTIES.	CARBONIFEROUS.			DEVONIAN.			SILURIAN.											ERUPTIVE ROCKS.					
					Devonian, or old red sandstone.			Upper.			Middle.	Lower.			Primordial.									
		Millstone grit.	Carboniferous or mountain limestone.	Lower shalls.	Upper.	Middle.	Lower.	Ludlow series.	Wenlock series.	Woolhope limestone.	Llandovery series.	Caradoc beds.	Bala beds.	Llandeilo flags.	Tremadoc slates.	Lingula flags.	Cambrian.	Laurentian.	Granite.	Syenite.	Felstone dykes.	Basalt.	Greenstone.	Metamorphic rocks.
N.	Northumberland	+	+																			+	+	
	Cumberland	+																						
	Westmoreland																		+					
	Durham	+	+																					
N.E.	Yorkshire :—E. Riding																							
	N. Riding	+	+																					
	W. Riding	+																						
N.W.	Lancashire	+																						
	Cheshire	+	+																					
	Denbighshire		+						+	+														
	Carnarvonshire								+					+	+									
	Anglesey																							
	Flintshire		+														+							
E.	Lincolnshire																							
	Rutlandshire																							
	Norfolk																							
	Suffolk																							
E.M.	Derbyshire	+	+																					
	Nottinghamshire				+																			
	Leicestershire																	+						
	Northamptonshire																							
	Huntingdonshire	+	+																					
	Cambridgeshire																							
W.	Merionethshire								+		+	+	+											
	Montgomeryshire										+		+											
	Cardiganshire										+													
	Radnorshire				+		+		+					+										
	Pembrokeshire										+			+										
	Carmarthenshire						+				+	+	+	+			+							
	Brecknockshire				+		+																	

W.M.	Staffordshire																																									+	+	+								+															
	Shropshire																																				+		+								+		+	+	+		+	+	+	+			+								
	Warwickshire																																				+					+																								
	Worcestershire																																				+		+			+	+									+	+															
	Herefordshire																																															+		+	+			+														
S.E.	Bedfordshire															+	+	+					+		+	+		+																																				
	Hertfordshire											+	+	+		+																																															
	Essex			+	+							+	+	+	+	+																																															
	Middlesex										+	+	+	+		+																																															
	Surrey										+	+	+	+	+	+	+	+	+	+																																											
	Kent											+	+		+	+	+	+	+	+																																											
S.	Oxfordshire											+		+		+	+	+			+	+	+	+	+	+	+	+	+	+	+																																
	Buckinghamshire		+									+		+		+	+	+			+	+	+		+	+	+	+		+																																	
	Berkshire										+	+		+		+	+	+				+	+	+	+																																						
	Wiltshire	+															+	+	+				+	+	+		+	+																																			
	Hampshire					+	+	+	+	+	+		+			+	+			+													+																														
	Dorsetshire															+	+		+	+	+		+						+																																		
	Sussex										+		+			+	+	+	+	+	+										+																																
S.W.	Glamorganshire																																						+																								
	Monmouthshire																																			+																											
	Gloucestershire																								+		+			+	+		+						+										+														
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* Compiled and abstracted from—R. Tate's "Geology;"
Sir Charles Lyell's "Geology;"
Maps and Reports of Rivers Pollution Commission (Map by E. Best, Esq.);
"Geology of Counties of England and Wales," by W. J. Harrison, Esq.

TABLE D.

Staff Required in Departments for the National Hydraulic Board or Commission.

1. Survey:—

To make complete levels of departments and districts.

2. Hydraulic or Engineering:—

To report on present resources, including wells, lakes, rivers, and streams. Also to give accounts of existing works and machinery;

To determine upon and supervise execution of future works.

3. Statistical:—

To report on population, habitations, factories, quantities required, and to compile statistics generally.

4. Mechanical:—

To report, advise, determine on, and take charge of machinery.

5. Geological:—

To report fully on the hydro-geology of all districts.

6. Chemical:—

To give analysis of various waters, &c., as may be necessary.

7. Meteorological:—

To report on rainfall of each districts, with account of mist fall on hills, and wind pressure of the nation.

8. Finance:—

Including Assessors, Collectors, Accountants, and Paymasters.

PAPERS.

METHODS OF SECURING A SUFFICIENT SUPPLY OF PURE WATER.

THE INCIDENCE OF RATING FOR SANITARY PURPOSES IN RURAL DISTRICTS.

By A. H. Brown, M.P.,
Vice-President of the Society of Arts.

In rising to bring this subject before the Conference, I feel that it is one of considerable magnitude, and one on which I am afraid there is some difference of opinion. For some years I have been watching the working of the Public Health Acts in the rural districts, and have endeavoured, if possible, to find remedies for the difficulties, where there appeared to be need of a remedy. I have now to bring before the Conference a point which I feel sure is one of the great obstacles that prevent the successful working of the Public Health Acts. Sanitary improvement, like every other improvement, cannot, I am afraid, be carried on without money. The way the money is raised for certain sanitary purposes is the reason why I ask the Conference to grant me their attention for a few minutes. I ask them to consider the incidence of rating for water supply and drainage, and whether a better incidence of rating cannot be devised. Let me say, at the outset, that I have no intention of raising the question of rating income; what I want is the proper apportionment of the expense on houses and lands. I hope gentlemen who follow me will keep to the narrow issue I have raised. The present mode of raising money for sanitary purposes is that an area is taken—such as a parish—and upon that area a rate is laid, which falls equally upon all the property within the area. There is an exception in the case of agricultural land, about which I shall speak presently. In some cases there are special drainage districts; but I shall show that they do not meet the difficulty. I may mention that urban districts have the power of making a separate assessment upon a part, or parts, of the district. Now, if all the property within the area were equally benefited by a sanitary improvement, the plan of levying an equal rate would be fair; but, in almost all cases, some property is not benefited at all, or only in an indirect manner, while other property receives the full benefit. Take the case of a parish with a village, which has to be drained or supplied with water, in the centre or at one end, and with a lot of agricultural land around it. Is it right or fair that all the land should be rated for the drainage water or supply of the village? Or take the case of a parish with two villages, one of which is to be drained or supplied with water; is it right that the other should help to pay for the cost? Or take the case where there are two landlords; one an improving landlord, the other not. Is it fair that the first, after he has improved his own property at his own expense, should have to pay for the improvement of the property of the other? Or, if you take another case, where a speculative builder has run up a lot of houses, is it right that the cost of draining those houses should be borne by the parish? What do we find actually to take place? In parishes where any sanitary improvement is to be effected, there immediately spring up two parties, one for, and the other against, the proposed works, those whose houses are not going to be benefited objecting to pay for the improvement of their neighbour's property. A case of this sort was mentioned by Colonel Cox, of the Local Government, Board, when he gave his evidence before the Select Committee of last year on the Public Health Act Amendment Bill. He said, in answer to a question put to him—

> "I have one case particularly in my mind that occurred very recently, but it is not by any means an uncommon one. It was a question of supplying with water a small village called Tal-y-Bont in Brecknockshire. The village of Tal-y-Bont was at one end of a contributory place some 12 or 13 miles long; it contains about one-third of the population of the parish; the remaining population—that is to say, the two-thirds not in the village—occupied detached houses and farms. Opposition was most vigorous, and not unnaturally so, on the part of those people. They said, 'We two-thirds have got to put our hands into our pockets and pay for the express benefit of the remaining one-third; and those people whom we are supplying with water are perfectly well able to supply it for themselves, and the whole thing is wrong.' The opposition was extremely fierce and obstinate on those grounds."

Many other instances were mentioned by Sir Baldwin Leighton and others, of villages where the population was scattered over a large area, and where those who were not benefited by the improvements objected to pay. With regard to this state of things, the Committee of last year reported that it was productive of grave evils. The report says:—

> "It frequently happens, notably in rural districts, that the whole charge is borne by the parish, under the rate for special expenses, while the supply of water is limited to the village, or a particular part of the parish. Those, therefore, who live outside the village, or the part of the parish benefited by the supply, have to pay for the water from which they derive no advantage; this fact causes great opposition to schemes for water supply, and in many instances renders it impossible to carry them out."

The same reason prevented the execution of drainage works. The Committee, to which I have referred, had before them the evidence of Dr. Ballard, of the Local Government Board, who was able to mention, case after case, where villages required draining, and where the public health had suffered in consequence of nothing having been done in the way of drainage. Why was this? The reason was, because those who administer the law knew that great opposition would be raised, and not unjustly raised, if they attempted to levy a rate on all, which was only for the benefit of a few. Perhaps I shall be told that what is wrong is the area, and that the area ought to be altered. But in most cases, the area is the parish, and to alter the area of a parish for sanitary purposes only is impossible. They are very ancient, and so interwoven with what we call local government, that such an idea has only to be stated to show its impossibility. But I shall be told that there is a provision for making special drainage districts in the rural parts of the country. But these special drainage districts are found, in practice, not to work well. I have made inquiry on this point, and have received information from 105 medical officers of health, who have the supervision of 6,500,000 acres of land, and 2,000,000 of the population of this country in 37 out of the counties of England and Wales. Only 26 out of the 105 medical officers were able to say that application had been made to the Local Government Board for the formation of a special drainage district, some of which had been refused. On this subject, the report of the Committee of last year contained the following observations:—

> "Special districts for drainage and water supply have been in some cases formed, but objections are often raised to the formation of new rating areas, and in some cases special difficulties arise. For instance, when in a village some of the houses have water and some have not, and when these two classes of houses are intermingled."

I think I have said enough to show that special drainage districts are not very successful. Let me now deal with the objection that the parish ought to pay, and that it must be treated as a whole. It is argued that the villages contain the labour which is used on the land, and therefore, it is fair to tax the farmers for the benefit of the labourers. But this is often not the case. The villages often have a special industry. Take, for instance, a mining country, or suburban places, where the labour belongs to the town. In such cases there is no benefit to the farmers, and their land ought not to be rated. Again, it is said that if the rates do not fall upon the parish, no sanitary improvement will take place; and, consequently, disease will spring up, and the poor rates will be increased. The answer to this is that, if you make the incidence of rating fair—which it is not at present—opposition to sanitary works will decrease, and, therefore, the public health will be improved. On this subject Sir Baldwin Leighton said:—

> "Then there is the argument that the parish is interested in these improvements, because if they are not made, it will have to pay for medical relief, if not for pauperism. That I think is a fallacious argument. The other argument is that the village contains the labour of the district and, therefore, that the surrounding land ought to pay for it; but that I think is as great a fallacy as the other. In the first place, the village does not contain that labour; in my part of the country it hardly ever does; the labour is contained either in the farmhouses or in detached cottages. There are instances of suburban villages where the labour really belongs to the town, and not to the country; but being in the district of the rural authority, it would be thrown upon the parish."

Having shown that there is a great opposition to works for sanitary purposes, and that there is nothing in the present law to remove the opposition, I come now to suggest the remedy. In dealing with the question of water supply, the Committee stated in their report that, after full consideration, they—

> "Think that the sound principle to lay down is that the water supplied by a sanitary authority should be paid for by the consumer. It is obvious that a fair charge made directly on the houses benefited will tend to disarm the opposition which now arises on the ground that the cost of the water-works will be thrown on the rates."

Let the same principle be applied to drainage; and when a house is drained, let the cost of the works be a charge upon the house which is benefited. But I shall be told that this would require a great alteration in the law of rating. No doubt this is true; but the principle is not new. The principle is found in the Public Health Act itself as regards nuisances; for the cost of removing a nuisance is borne by the property to be benefited by the removal of it. The same principle is in operation with all water companies, for there the cost of water is paid for by the consumers. As regards drainage, we find the same principle adopted in many Acts of Parliament. It is admitted in the Public Health Act; for under the provisions of this Act it is possible to charge the property benefited with the cost of the works in some cases—I mean those cases in which a private improvement rate is levied. It is also admitted in various local Acts, thus pointing conclusively to the policy of extending the principle I contend for into general law. For instance, in the Hereford Improvement Act, 1872, I find the following power to levy sewer rates. I need not read the whole of the section—the important part of it is that—"A sewer rate is to be levied upon the houses, lands and tenements, the drainage of which is connected by pipes with any such sewer or drain;" and in order to make it perfectly clear what the rate is for, the section concludes by stating that the rate is to be in lieu of any rates for making sewers under the authority of the Act of 1854. Again, I will quote the case of a large town—Liverpool—where part of the cost of the sewers falls directly upon the house drained by them. The Liverpool Sanitary Act says as follows:—

> "Be it enacted that when and as soon as any such house or building shall drain into or communicate with any sewer vested in the Mayor, Aldermen, and Burgesses, the owner of such house or building shall pay to the Council a sum after the rate of six shillings for every lineal yard of the frontage of such house or building towards the principal street in which the same shall be situated."

I am aware that there are difficulties in the plan adopted in this case; but the principle is the same. Again, to quote from one more local Act—the Black Rock Local Board Act, 1876, has the same principle with regard to water. A section of the Act is as follows:—

> "The Local Board may demand and take for the supply of water for domestic purposes within the district any rates and charges not exceeding the rates and charges following, that is to say, where the annual rack rent or value of the premises so supplied with water shall not exceed twenty pounds, at a rate per centum per annum not exceding seven pounds ten shillings."

As the power of rating is here limited to premises supplied with water, it is evident that they cannot rate premises not so supplied; or, in other words, the Board are recouped for their expenditure by charges on the property benefited. I have noticed that there have been several allegations against the principle I have laid down, and these I will now glance at. First, it is alleged that the proposal would exempt agricultural land from rating, and that already this class of property is partially exempt, being rated at only one-fourth of its value, and in this manner it already enjoys an unfair exemption, for it ought to pay more than it does to the highway rate. The answer to that is this—that each rate should be considered on its own merits, and in relation to the public good to be effected; and it is no answer to say that one can be put off against the other.

But I shall be asked whether this principle extends to urban districts. In any closely-built town you find the principle I am contending for is in operation, for every house being drained or supplied with water by the public authorities has the benefit of such water and drainage, for which it has to pay the rate. These are border cases, districts which have urban powers, but are rural in their characteristics; and I, for one, do not deny that there is considerable difficulty in dealing with them. Again, it is said that it would destroy the security on which money has been lent—I mean the security of the rates of the whole parish. But that is not the case, for the rates of the whole district would be the ultimate security, and would be mortgaged, though the rates on the property benefited would be the first asset for the repayment of the interest and principal of the mortgage. With reference to the objection that, under the proposal I make, the areas might be very small, and, therefore, the rating might be high, I think the objection is a good one in those cases where, from various circumstances, the cost must be great; and, therefore, I think it would be necessary to put a limit of charge upon the property benefited, and any excess of charge should fall as it does now. This is a difficult and technical subject, and I am afraid I have failed to put it clearly before the Conference.

The object I have in view is to diminish the opposition which, at present, exists to sanitary improvements in rural districts, and this object I believe can be attained by relieving ratepayers from the injustice of contributing to improvements by which they are not benefited. If anything in this direction could be effected, I believe it would be a great improvement; and, therefore, I have brought the subject before the Conference. One further remark I would make before sitting down. It appears to me easy to see how the present state of the law has arisen. Sanitary legislation has been a system of growth. The wants of populous places have received first attention, while those of thinly inhabited districts have been neglected; and we have made the mistake of applying to a thinly-inhabited district the laws which should apply to a more complex form of society. It would, I think, have been more scientific if the wants of a simple form of society had first been attended to, and afterwards there had been grafted on to those principles the developments necessary to a more complex form of society.

ON THE UTILISATION OF THE WATER SUPPLY OF ENGLAND.

By Francis R. Conder, C.E.

At the time when public attention in England was sharply directed to the sanitary condition of the country by the serious illness of H.R.H. the Prince of Wales, in 1871, the writer submitted to the Local Government Board a plan for the sanitary and hydrographic survey of the country, and for the division of England into an organised system of districts for that purpose. For this plan, that of the creation of independent and disconnected local authorities was unfortunately substituted by the Government, and the opportunity for efficient organisation was thus thrown away. In July, 1873 (with the assent of the president of the Local Government Board), an article to some extent sketching out the original scheme was published in the "British Quarterly Review," and from that date the subject has from time to time been advocated by the writer in different publications.

On the appearance of the letter of H.R.H. the Prince of Wales to the Chairman of the Society of Arts, dated 30th January, 1878, the writer, referring to the above facts, submitted a paper on the water supply of England and Wales (accompanied by a map), which the Prince sent to the Council of the Society. The paper is printed on p. 40 of the official account of the Congress held in May of last year. From the same report it appears that the writer proposed that the result of the discussion then pending should be put in the form of a resolution, which suggestion was at once adopted by the Chairman; and a motion to that effect, framed by the Council, was moved on the 22nd May by Dr. Wright, seconded by the writer, and carried unanimously. This resolution recommended the Council of the Society to make application to the Government to appoint a commission to investigate and collect the facts connected with water supply in the various districts throughout the United Kingdom.

The invitation by the Council of the Society of Arts of suggestions for the division of England into watershed districts, can only be properly responded to by bearing in mind the conclusion thus arrived at—that of the pressing need of a complete hydrographic survey of the country. In the absence of that indispensable information, the reply of the engineer to such questions as those proposed can only be, to a certain extent, guess work.

Indeed, the President of the Institution of Civil Engineers replied to the inquiries of the Council of the Society of Arts, in the spring of 1878, that he saw no way in which a large and comprehensive scheme of a national character could be brought forward, owing to the difference of condition in different districts. This rather discouraging opinion was published by the Council.

Of the other papers brought before the Congress (on 21st and 22nd May, 1878) that of Mr. Brown, M.P., called attention to the provisions of a Bill he had introduced into Parliament for the amendment of the Public Health Bill. Mr. J. W. Willis Bund proposed the appointment of a proper body to watch over the water supply, and the provision of funds to carry out the plan. The Rev. J. C. Clutterbuck insisted on the necessity of an extended and accurate knowledge of the amount and distribution of the rainfall of England, including the absorption of water by impervious strata. Sir Henry Cole thought that the whole kingdom might be mapped and parcelled out into a sort of water heptarchy. The writer gave a brief sketch of the main features of the inquiry, and of the division of England into chief outfall provinces. Mr. Bailey Denton expressed his view of the necessity of a conservancy of river basins, of the acquisition of a knowledge of their hydro-geological conditions, and of the provision of legal facilities for dealing with the water. Mr. De Rance pointed out that the sanction of private applications for Acts of Parliament for water supply, in the absence of a general survey of the country, might be very mischievous, and gave a table showing the chief geological formations of the river basins on the northern, eastern, southern, western, Welsh, and north-wests coasts of England. Mr. Evans called attention to the sources of subterranean supply. Mr. Hassard spoke of the Welsh gathering grounds. Mr. Homersham dwelt on the advantages to be secured by the educated engineer from the careful study of data. Mr. Lucas urged that the general absence of data as to water was the only real difficulty in the case; and that a national survey would provide the remedy. Mr. Parry proposed the division of the country into watershed districts, each under the charge of an engineer, and suggested the existence of 25 watersheds, each exceeding 500 square miles. Mr. Pierce argued as to the necessity of a national supply of water, and that to be provided by the Government, instead of by the Local Boards. Mr. Prestwich took a general view of the water-bearing strata of the country. Mr. Shelford suggested that power should be given to county Boards to deal with the catchment basins, of which he enumerated 215. Mr. Shute spoke of artificial lakes, but gave no figures. Mr. Symons referred to the rainfall statistics, and recommended that the entire administration of streams should be brought under a single direction. Mr. Wills pointed out the inadequacy of local authorities to deal with the question of water supply.

Thus, the whole *consensus* of the proposals of 20 different scientific men, sent in without any mutual knowledge, follows the lead of the proposal made to the Local Government Board by the writer in 1872; and the resolution of the Congress added the sanction of the unanimous consent of all its members. The utter ignorance in which engineers now are of many of the actual facts —as admitted by the president of their Institution —the imperative need for their collection; the necessity of Government impulse and direction for such a collection; and the propriety of dividing the island into national watershed and outfall districts; must be taken as points which it is no longer requisite to discuss.

Such being the present state of the question, it is evident that the suggestions that can now be usefully submitted to the Council of the Society of Arts must be limited in their range. It is unnecessary to urge further the need of information, and it is useless to attempt any detail of recommendation in the absence of the requisite data.

It may, however, be of use to say something as to the principle of the watershed divisions of the country, and also of the steps which it is competent for the hydraulic engineer to take, if called on to advise in any particular line.

From the fact that the entire water-supply of the country originally descends upon its surface in the form of rain, snow, hail, or vapour, it follows that the first duty of the hydrographer is to ascertain the lines of watershed or water-parting; and then to measure the quantity of rain which annually falls in each district thus physically divided by nature. The lines of water parting will not be, in all cases, exactly those of the summits of the hills. But in the first instance the latter, forming the orographic divisions of the country, require to be clearly mapped out. The lines of watershed once defined, the next steps will be to measure the rainfall within each district, and then to ascertain what becomes of the whole.

The physical form of Great Britain (with the portion of which island forming England and Wales we only have now to do) indicates the primary division of the outfalls of the eastern, the southern, and the western coasts. The great central line of hills called the Penine chain, running from Warwickshire to Scotland, forms one primary watershed line. The Cotswold range divides the affluents of the Severn from those of the Thames. A more detailed study is needed to indicate the division of the head waters of the large basins of the Ouse and the Trent from the affluents of the Thames and Severn. The line of chalk downs running from Deal to Devizes divides the Thames catchwater basin from the sources of the southward trending rivers that fall into the English Channel. The granite upheavals of Devonshire and Cornwall divide the rainfall of the western prolongation of the irregular form of the island, between the English and the Bristol Channels. The Welsh mountain streams, whether turning off their rainfall to the east into the Severn, the Dee, and the Mersey, or directly westward or southward into the sea; and the rivers of Lancashire and Cumberland, drain the western portion of our coasts.

In descending from this general physical division of England to the smaller watershed divisions, there is room for some difference of opinion. The unit of the water system is a river basin, included between the watershed and the sea. But these units differ so extraordinarily in size, that some mode of grouping them becomes a matter of administrative convenience, or even necessity. Thus, while one engineer has sketched out 10 main outfall provinces, Sir Henry Cole has spoken of a water heptarchy. Mr. De Rance has tabulated 14 river systems, under six general heads, and Mr. Shelford has enumerated 215 catchment basins, which vary in area from under 100 to above 6,000 square miles. It is evident that administrative convenience must be consulted fully as much as absolute principle in carrying out the first general division of the rain outfall of the island.

With regard to the three largest of these districts, there is little room for hesitation. The Ouse and the Trent with their affluents drain an area which Mr. De Rance estimates at 9,457 square miles. The Thames and its affluents, including the Medway, drain an area estimated by Sir Henry James at 6,160 square miles. The Severn and the Wye, are estimated from the Ordnance map, by Mr. De Rance, as draining 9,248 square miles. Thus these three easily distinguishable systems comprise an area of 24,865 square miles, or 40 per cent. of the whole map of England and Wales. The definition of these watersheds at once fixes the boundary of other districts, and indicates the respective magnitudes into which it will be convenient to distribute them.

The east coast of England, after the abstraction of the outfall of the Humber and the Thames, is naturally divided into two districts, one lying north of the first system, and the other intermediate between the two. The basins of the Tweed, the Tyne, and the Tees contain, according to Mr. De Rance's tables, 3,702 square miles. The rivers discharching into the Wash, drain 5,828 square miles, according to Mr. Sketchley, and together with the remainder, flowing from the eastern counties to the north of the Thames watershed, drain in all 10,053 square miles, being an area nearly 200 miles in excess of former estimates. If the whole of the western promontory of the island be included with the western outfall from the south limit of the Thames basin, the area will be 8,350 miles. The rivers of the Welsh coast, westward of the outfall of the Taf and the Ely, into the Severn estuary, drain 4,378 square miles of country. The eighth district, in this order, is that drained by the Dee, the Mersey, and the Duddon, comprising 4,556 square miles. And the remainder of the western coast, from the Esk to the Eden, is confined in the comparatively small area of 1,758 square miles, which might, it is possible, be conveniently placed under the same administration as the first district, or that of the Tweed, Tyne, and Tees.

The divisions thus indicated differ from the sketch plan submitted to H.R.H. the Prince of Wales, only by the substitution of the measurements taken by an officer of the Geological Survey for the round figures taken from less accurate maps, and by a slight change in some of the distributions then made (such as that of the allotment of the Usk to the Severn system), for the sake of adhering to Mr. De Rance's measurements. The total area thus accounted for is 57,374 square miles. The total area of England and Wales, according to the agricultural returns, is 58,311 square miles; which figures were taken in the sketch distribution of May, 1878. The smaller total is now adopted, in accordance with the tenor of the invitation of the Council, "founded upon evidence already published."

Subject to such minor questions, and to the decision, as a matter of convenience, on the adoption of 10, 9, or 8 divisions of the country, the above consideration must regulate the main lines of demarcation between the natural outfall districts of England. It is now desirable to inquire how the meteorological and geological portions of the inquiry are to be connected with the first sketch, taken from the physical geography.

The problem which the hydraulic engineer has to solve in any particular case may be regarded as threefold. It regards the quantity, the quality, and the cost of the supply. These elements depend on area of watershed, or quantity of rainfall, and on character of soil, not only orographically, but geologically, regarded.

As regards the first question, that of quantity, the first index to be offered to the engineer is the hydrographical map of the British Isles, prepared by Mr. G. J. Symons, a copy of which will be found in No. 66 of the "Transactions of the Institution of Surveyors." The annual report on British rainfall should be studied in connection with the map.

It will be seen from these authorities that the water supply of England is divided—as in the first instance we considered the water outfalls to be—into three districts, corresponding to the *quasi*-triangular form of the island. The rainfall is, however, heavier on the more elevated districts of country. It is more on the south coast than on the east, and more on the west coast than the south. The ten rainfall districts, or registration divisions of Mr. Symons, unfortunately do not coincide with the natural river outfall districts; the divisions of the Registrar-General, which are not based upon physical geography, having been adopted. The first requisite for making the best use of the observations already collected, as well as for completing them when requisite, will be the adaptation of the registration districts to the outfall districts. As to this, Mr. Symons is fully aware that it is desirable. But it is a costly process for an unsupported institution to undertake, and is one of the points which can only be thoroughly carried out as a part of the complete survey. In the meantime the approximate method of distribution which was applied in the author's sketch map of 1878, will have to be more minutely applied by the engineer in any district in which he is engaged.

Area, levels, and main rainfall being ascertained, the nature of the soil furnishes the next grand division of the subject. Soils, in principle, are either impervious, pervious, or partially pervious. From impervious soils the rainfall escapes in floods or torrents. In these formations are also to be found the great sub-aerial reservoirs of water known as lakes.

The question of the greater or less perviability of the soil is matter of special study. In principle, the pervious strata may be divided into those which, owing to their local and physical characteristics, absorb rain and yield it again in springs, brooks, or rivers, and those which, conveying the water they imbibe to a more considerable depth, carry it under ground to the sea, thus yielding a supply only accessible by wells, perhaps of great depth.

On the eastern coast, the lower carboniferous strata, the coal measures, and the magnesian limestone, tend to give the character of torrents to the rivers of our first district. The Lias, the Oolite, and the boulder clay then line the shore, to which the cretaceous beds approach near Flamborough head. The Trent and the Ouse drain 4,000 miles of permeable, as well as 3,500 of partly permeable, strata; and the hydrography of the district affords a sharp contrast to that of the more Northern division. The rivers that enter the Wash drain a large area of aluvial deposit, and are fed from the chalk and the oolite springs, as well as by torrent waters from the Lias. The Thames derives its head waters from the Oolite and the chalk, while the tributaries to its stream, in the lower part of its course over the tertiary clays, are torrential. The cretaceous and Lias beds, and tertiary deposits, line the southern coast, as far as the constriction between Lyme Regis and Bridgewater. Granitic, Cambrian, and Silurian rocks, impermeable or only partly permeable, send down the swift bright rivers of Cornwall and of part of Devonshire; though the Exe meanders through a poicilitic district, resembling that drained by the Warwickshire Avon. Severn receives contributions from almost every geological system; and having cut a deep narrow channel in the broad rich valley, which forms its bed below Worcester, affords an example, rare in England, of an annually enriching, and usually harmless, natural inundation. Great geological variety, on passing west and north of the estuary of the Severn, demands careful study. From 40 to 75 inches of rainfall rush down the slopes of the clay slates, trap rocks, and Devonian strata of Wales. The Mersey and the Dee drain a district not unlike that which is watered by the Trent; and north of the Ribble we again touch the torrential district of the lakes.

From this glance at the different physical conditions of the main outfall provinces of England, it will at once become apparent that any suggestions as to the further subdivision of the country into water supply districts, must, until the hydrographic survey is complete, either be brief and general, or partake of the nature of a treatise on hydraulic engineering. As the Society of Arts inserts, not volumes, but suggestions, the remarks which follow must be somewhat concise.

It will scarcely be disputed that, if an engineer be called on to advise on the water supply of any locality, his first duty will be to provide himself, as far as possible, with precisely that information which would be furnished by the general survey, if complete. Each locality must be regarded as forming an integral portion of the natural outfall district in which it is situated. Then the engineer will have to ascertain the area, as well as the physical, geological, and meteorological particulars, of the whole portion of the vicinity that lies between the locality he has to take in hand and the watershed of the basin. He will no less have to ascertain the natural capacities of the rivers, or other means of drainage, that will remove the water when supplied. It will be needful, in the first place, to ascertain the population of the district, and the probable increase, for at least, 30 years. The rough rules of 50 tons of water per annum for each unit of the population, and of 100 tons of water for every inch of rainfall, will give a first approximation between supply and demand. The annual rainfall, the annual evaporation, and the absorbent or non-absorbent character of the soil over the area on which the locality can naturally draw for supply, must be ascertained. Due care must be taken not to rob the gathering grounds of other towns or villages. The transgression of the natural watershed of a district is—unless there be special ground for exceptions—scrupulously to be avoided, both on the ground of cost, and on that of the propriety of allowing each the guidance of nature in the supply of its own district to follow need.

When such general observations have been made, the special character of the district will require study. Thus, in a mountainous country, of impervious strata, natural or artificial lakes may form the most efficient means of supply. In more permeable soils the natural resources of springs or brooks may be utilised; or enough water may be procured (as in the case of the East Kent Water Company) from deep wells. In impervious soils the water will generally have to be led from some distance, or procured from deeper wells than is requisite on permeable soil; as in the case of penetrating the Lias into the abundant water-bearing strata found to underlie it. In cases where the subterranean supply is derived from the chinks or crevices which occur in the lower chalk, the greatest care must be taken lest sewage pollution damage the supply. No less care will have to be exerted as to springs, brooks, and rivers, whether in the upper or lower portion of their course, with reference to the country which it is proposed to water and to drain. The aim of the engineer will always be to take his supply, if practicable, on such a level as to allow of constant service by the action of gravitation; and even if pumping be in the first instance necessary, the position of the reservoirs should be fixed at such a height as to ensure that this mode of supply should not be neglected. Questions of economy as to position of reservoirs, length of pipes and culverts, cost of pumping, and other details of distribution, will require special treatment in any case. The chief rules will be to ascertain the natural source of supply, to utilise it with due regard to all claimants, and so to balance the question of head and of lift, as to ensure the truest economy, combined with the greatest certitude of efficient supply.

By this careful treatment of any given locality in England, with due regard to its position, in any of our outfall districts, the special survey for individual cases may be so carried out as to form data for co-ordination hereafter in the general hydrographic survey. It is by this method alone that, pending the completion of the national work, individual improvements can be effected without incurring the risk of being hereafter found impediments to the general improvement of the district in which they occur. An ill-arranged local water supply, that should rob a more important district of its natural sources, that should interfere with the drainage of a valley, that should waste surface or subterranean stores, or that should poison rivers or land waters below the area, would become a dangerous nuisance, and ultimately a great source of expense.

The town of Guildford may be cited as an illustration of the truth of the above remarks.

Guildford is situated at the spot where the River Wey finds a passage through the long rampart of chalk that extends across Surrey in an easterly and westerly direction. Part of the town is situated on the chalk, along the axis of the downs, and part along the valley of the Wey. Both parts of the town were formerly well supplied with water from wells sunk in the chalk, and in the alluvium of the valley; and the Wey brought a copious supply of fresh water to the very doors of the low lying houses. Guildford, however, is not sewered. With the increase of the population, the wells became polluted by sewage matter. In the lower chalk the water makes its passage through chinks, and the sewage does the same, without oxidation. Typhoid fever became more and more prevalent, until some years ago the matter was thoroughly taken in hand. A well was sunk, for 30 feet below the level of the river, into the water-bearing stratum of the Folkestone beds; and a copious supply of pure water was pumped up to a reservoir on the hill. The town is now supplied with the most unexceptionable water, and has become perfectly healthy.

In this case it is clear that, while a thorough local knowledge was necessary, as pointing out the dangerous state to which the water-supply, on which the town had subsisted since the time of Alfred, had been brought by the growth of population, the scientific knowledge of the position of the locality in the limits of the Thames watershed basin pointed out the remedy. The watershed above Guildford covers an area of 230 miles. It was observed, during the progress of the Ordnance Survey, that not more than two-fifths of the rainfall over this area ran under the bridge at Guildford. A large proportion of the rain permeates the Folkestone beds, composed of ferruginous sands, which attain a thickness of 160 feet at Godalming, four miles above Guildford, and form a persistent stratum beneath the Gault. The body of water which thus flows towards the Thames is probably arrested and diverted seaward, by the palæozoic anticlinal which has been recently discovered. An ample supply for the south of London is neglected; but its source has been taken advantage of at Guildford with the best results. One example may be enough to show the application of the principles, as to the truth and range of which it is submitted that there is no longer room for doubt or debate.

THE WATER SUPPLY OF RURAL DISTRICTS.

By W. H. Wheeler, M.Inst.C.E.,

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By the amended Sanitary Act of last Session, which came into existence a few months since, it has become the duty of the Rural Sanitary Authorities of this country to secure to every cottage and house a supply of wholesome water, provided that such water can be supplied at a reasonable cost. The maximum fixed by the Act is a sum which shall not entail a greater weekly charge than 2d. for each house, allowing interest at the rate of 5 per cent. This represents a capital outlay of £8 13s. 4d.

In rural districts, where the houses are scattered, an organised system of supply from one general source, such as prevails in towns, is often impracticable at any reasonable cost, and, even where practicable for the supply of houses aggregated in a village, the unfairness of taxing a whole parish for one particular portion, and calling upon persons to contribute towards works from which they derive no benefit, is so inequitable as to make such detached local supplies often impolitic if other means can be provided. It is the purpose of this paper to show that it is quite possible to supply every cottage and house in the rural districts of this country, however isolated, with a sufficient quantity of wholesome water, at a cost not exceeding the limit laid down in the Act, and also, by examples of works already executed, to direct attention to the simplest and most effective way of carrying out, not only the provisions of this Act for the supply of water for domestic use, but also for agricultural purposes generally.

QUANTITY REQUIRED.

The minimum quantity that is sufficient for the supply of a cottage or small farm-house, for all ordinary domestic purposes, may be taken at 13¾ gallons per day, allowing 5½ persons as the average number to a house, and 2½ gallons for each person. This, of course, gives no margin for water-closets, baths, or other similar luxuries, which belong only to a larger class of dwelling. This quantity may appear small; but, having made extensive inquiries amongst cottagers and others, I found sufficient evidence to satisfy myself that it was the full quantity that was used when the water had to be baled or pumped from a tank, and not left to run to waste from a tap. Mr. Easton, the eminent water engineer, in his evidence before the Select Committee on the Public Health Act Amendment of 1878, stated that, as the result of his experience and inquiries amongst cottages in Sussex, he was satisfied that this quantity was sufficient. Col. Cox put the quantity at three gallons a day, and the other witnesses agreed with the estimates of Mr. Easton and Col. Cox, some even putting it at less. In the sixth report of the Rivers Pollution Commissioners is given an instance of four cottages provided with a tank, in which the rain water was collected from the roofs, one of the inhabitants being a laundress, who used a large quantity of water, and another feeding a number of pigs. The size of this tank was barely sufficient to give 10 gallons a day to each cottage, yet it is stated that it had never failed to maintain a sufficient supply.

The large quantity used in towns, varying from 20 to 30 gallons a head, is due partly to manufactories, street watering, and flushing sewers, but principally to waste. This is proved by the fact that towns supplied by meter do not average more than seven gallons a head, and by the test applied to several streets in Brighton, where it was found that the supply did not average more than 4¾ gallons a head, although the number of persons to a house would be above the average, and water-closets and baths be freely used.

RAIN WATER SUPPLY.

The simplest means of supply is by collecting the rain as it falls from the heavens, and storing it in tanks.

The doubt which was for a time cast upon the wholesomeness of this source of supply by the Rivers Pollution Commissioners, by the statement in their sixth report, that rain "is in reality water which has washed a more or less dirty atmosphere, and is laden with mineral and excrementious dust, zymotic germs, and the products of animal and vegetable decay and putrefaction" has, I think, been now sufficiently dispelled, and the above statement considered to be only a fanciful effort of imagination in which not one of the scientific witnesses examined by the Select Committee of last year agreed. Mr. Rawlinson, in reply to a question on the subject, said that "he did not believe one word of it," and that "if only one-tenth part of what is said about water happened to be true, his only surprise was that a human being lived on the face of the earth." Certainly, as far as the Fen districts, with which I have an intimate knowledge, are concerned, if rain water contains the zymotic germs and other impurities mentioned above, these must be much more wholesome drink than they are generally supposed to be, for there scarcely any other water is used.

With regard to the impurity of rain water, Dr. Ballard remarked, in his evidence before the same committee, that although some simple system of filtration might be desirable, he did not consider any enactment on the subject necessary, as in country districts the only chance of pollution of rain water from the roofs would be the excrement of birds and dead leaves blown in the gutter, and that the amount of this would be so trifling as not to produce any mischief; with this Mr. Easton agreed. Sir Harcourt Johnson also stated that in Yorkshire he had employed rain water tanks, with great success, for the supply of the cottages, and in no instance had there been a failure of a tank; that he had drunk the water out of these cemented tanks, and found it exceedingly good, and in summer remarkably cool. Mr. Clutton also spoke as to the general and satisfactory use of tanks for the cottages on the estates for which his firm acted. Soot from the chimneys is by some persons added to the list of impurities, but although this may give the peculiarly flat taste which unfiltered rain water has, yet, being nothing but carbon, it may fairly be considered as a purifying agent, to rectify any harm that may be likely to arise from the leaves and excrement. Simple filtration through charcoal and sand, immediately before use, entirely removes this flat taste, and makes the water bright and sparkling. If the filter be so constructed that the charcoal, when not actually filtering the water, is exposed to the air, it will remain serviceable for a considerable time. To keep the water sweet, provision should always be made for the admission of air into the tank in which it is stored, but, to prevent the growth of vegetation, it is necessary to exclude the light.

Granting that 2½ gallons per head is enough for all the ordinary domestic requirements of a cottage, sufficient rain falls on the roof of every house in the course of a year, if properly stored, to yield a full supply.

A cottage with its outbuildings covers about 500 square feet of ground. Taking the rainfall at 22 inches per annum, the quantity that may be relied on as an average in the driest districts of the country, a slated roof will yield 5,700 gallons, equal to a daily supply of 15⅝ gallons, or rather more than 2¾ gallons per head. Tiled roofs would yield less than this, being more porous than slates. Thatched roofs may be considered as altogether unsuitable for the collection of rain water, from their absorbent nature, the difficulty of providing spouting, and the chance of pollution from the organic matter in the decaying straw.

The rainfall being distributed over the whole of the year, the storage tank is constantly being replenished. With rainfall collected from land, large provision has to be made for periods of drought and for the decrease in the supply during the summer months, owing to the great amount of evaporation from the dried-up surface of the ground, and the water absorbed by the growing vegetation. With the supply from roofs, the circumstances are different. On an average of years, the heaviest rainfalls will be found to occur during the summer months from thunder-storms, nearly the whole of which will be stored. Having carefully calculated the daily demand as against the supply from the rainfall for the east of England, I found that the tanks ought to be large enough to hold 78 days supply, and having constructed a great number based on this calculation, experience has proved its correctness.

Assuming the available rainfall to be 22 inches, and allowing for storage for 78 days' supply, the proportion of tank room to roof should be 2½ gallons for every square foot of ground covered for cottages, or rather less for farmsteads and large buildings. Thus, a tank for a cottage covering 500 square feet would require to be 6 ft. 6 in. in diameter and 6 ft. deep up to the springing of the dome, and hold 1,200 gallons; but, in all cases, it is better to allow a greater capacity than is actually required, to prevent the pipe from the pump going too near the bottom, or the settlement being stirred up by the bucket or bailer. The best form for small tanks is circular, as being the strongest, and giving the greatest capacity for its outline, and, therefore, cheapest. For larger tanks, the form should be oblong, with circular ends, or, at least, the interior angles filled up. The ordinary method of construction is with brickwork, rendered with a coating of cement inside, domed over, and finished with a stone and iron lid let into a rebate, the water being obtained by a small iron bucket fastened on the end of a pole. For cottages, this is simpler and less expensive than a pump—which frequently requires repairs—and is less wasteful of the water. When the soil is porous, the tank may require puddling round with clay. When bricks are not easily procurable, or when several tanks have to be made, concrete, mixed with Portland cement, forms a better and more trustworthy material than brickwork. Mr. Clutton informed the Committee of last Session that he was now using concrete for all the cottages built on the estates under his management.

Taking the ordinary average price of materials and labour in the country—and there is not any great difference now between one place and another—a brick tank, properly cemented, domed over, and finished with manhole and cover, may be estimated to cost at the rate of 1¼d. per gallon. Larger tanks may be reckoned at 1d. per gallon, and hence there is economy in making one tank for the supply of two, or even three cottages. At this rate, the cost of the water supply for an ordinary cottage would be £6 5s., well within the limit laid down by the Sanitary Act.

Churches and schools might be made valuable aids in supplementing a village supply. The tanks for receiving this would not necessarily be constructed in the churchyard, but could be placed near to a group of houses, the water being conveyed to it from the roof spouts by iron pipes. An ordinary village church covers about 7,000 square feet, and the schools 1,000 more; these together would yield over 90,000 gallons a-year, sufficient for 16 cottages.

The Baroness Burdett Coutts has, in a village on her property in Wiltshire, had a tank constructed to take the water from the church, and it was found that as many as 120 buckets of water were counted as being fetched in one day—the villagers esteeming the work as one of the greatest acts of kindness that could have been done for them.

SUPPLIES FOR AGRICULTURAL PURPOSES.

Beyond the ordinary requirements for domestic use, farmsteads require a considerable quantity of water for the stock in the yards, for threshing and other purposes, but the roofs of the cattle sheds, barns, stables, and other buildings, are capacious enough to collect a sufficient supply. It is very rarely that new buildings are erected without proper provision being made for collecting the water from the roofs, and on all well-managed estates the old buildings are now spouted. Formerly, no doubt, it was the practice to allow all the rain to drip from the roofs on to the ground, not only to the detriment of the brick walls, but also soaking the ground and making the yards wet and cold; thus, while the available supply was wasted, in summer water had to be fetched in carts for the stock from a very considerable distance, an instance being given of a case in the east of England when there was no fresh water available within 15 miles.

Taking a typical case of a homestead for a farm of 100 acres of mixed land. The minimum requirements would be about 30 gallons a day for the house, 50 gallons for the stables and cow-sheds, &c., together 29,200 gallons in a year. To this must be added about 20,000 gallons more for threshing, and watering the stock in winter, or a total of 49,200 gallons. The roof of the farmhouse would cover about 1,000 square feet, and with 22 inches of rainfall yield 11,419 gallons, or a little more than 31 gallons a day. The farm buildings and sheds would cover about 3,500 square feet, and collect 30,965 gallons, equal to a supply of 110 gallons a day.

The supply for stock in the fields during the summer months is equally a matter deserving consideration. On the high lands on the Oolite or other absorbent formations when laid down as permanent pasture, or if arable land, during the time they are in seeds, water must be provided for the sheep and cattle to drink. This is generally done by sinking deep wells and pumping the water up, or by carting it. A little calculation would show that it would be far more economical to gather and store the rainfall in brick tanks.

On the downs and high chalk lands provision is often made by constructing what have hitherto been termed "dew ponds," from an idea that they collected the dew, but really these ponds are nothing more than collecting grounds and receiving tanks. They are made with exceedingly flat slopes, terminating in an almost conical bottom, are puddled with clay and chopped straw, and thus made impervious to the rain which, falling on the sides, is collected in the bottom, the summer showers yielding a quantity sufficient to replace the loss by evaporation, leaving the winter store for use. In one of these ponds in Berkshire, where observations were made by Mr. Slade, C.E., and published in a very interesting pamphlet, it was found that taking the period from the beginning of June to the end of September, a fall of 11¾ inches of rain on the surface of the pond, 69½ feet in diameter, yielded 23,043 gallons, which, as nearly as possible, balanced the quantity lost by evaporation; the supply for drinking of the sheep, which only amounted to 6,203 gallons, being obtained from the rain stored during the winter. A very wasteful way for providing and storing water. The cost of constructing the pond was £40. A brick tank of sufficient capacity to yield a similar supply would only have cost £12. A collecting ground 26¼ feet in diameter, made in a dished form, and covered either with cement, concrete, or asphalte made with tar and gravel, would cost from £3 to £5 more, and yield sufficient rainfall to fill the tank. Thus, while the cost would only be three-eighths that of the pond, the area of the ground occupied would be about one-sixth. If the collecting ground assumed the form of a shed, which would also answer the purpose of sheltering the stock from the sun, the total cost of shed and tank would not be more than that of the pond.

A tank placed in a corner where four fields meet would serve not only for drinking purposes, but also for supplying the engine during the process of steam cultivation. The constantly increasing use of steam power in cultivating the land renders a ready supply of water a necessity to the economical working of this agent. Every acre of land that is cultivated by steam requires from 100 to 125 gallons of water in addition to that used for driving the thrashing machine, which may be put at from 50 to 60 gallons per acre. Hence a further necessity of storing water and providing reservoirs readily accessible to the fields requiring cultivation. On impermeable soils storage can be accomplished by sinking ordinary ponds, at considerably less expense than making tanks. Messrs. Howard, the well-known makers of cultivating machinery, have on their farm in Bedfordshire so designed the drainage that it supplies a tank or pond at every site occupied by the engine during the tillage of the whole of the estate, and at the homestead a reservoir has been excavated in the clay which holds half a million gallons of water.

In districts where water is plentiful, the supply for agricultural purposes may probably be more advantageously distributed by a system of pipes covering the whole country. Sir Harcourt Johnson, in his evidence before the Committee, stated that on the estates with which he was concerned in Yorkshire, on some of the large farms the water was raised by rams and conveyed to every single pasture field, and the water itself carried into the houses and laid on in the back kitchen of every cottage of a whole parish. On one farm, the rental of which was £380 a year, the water was laid on to the farm premises, and to every pasture field with troughs and ball cocks, at an expense of £336, the farmer considering it such a boon to him to have the water at all times in the summer without the necessity of conveying it by means of horses and carts, and barrels, that he willingly paid five per cent. on the outlay in addition to the rent of the farm. On another estate, £480 was expended in putting down a ram and laying two miles of pipes communicating with the yards, houses, cottages, and pasture fields, on every farm.

SUPPLIES FROM GATHERING GROUNDS.

Where several houses are aggregated together in a village, some of which would be occupied by persons requiring a larger supply than is sufficient for cottages, a more organised system would be required and could be carried out more economically than by a number of separate rain-water tanks. Where no natural springs or similar sources of supply are available, collecting grounds and storage reservoirs must be resorted to. Speaking generally, every acre of drained land in this country may be taken to yield about 45,000 gallons, allowing only two inches to be stored out of the total rainfall. The proportion of population in the rural districts to acreage allows about 1·64 acres to every person, so that the supply is far in excess of the demand. For the supply of a small village, with mansion, vicarage, garden, stables, farmsteads, and cottages, a gathering ground of from 50 to 100 acres would be ample, and a reservoir 7 feet deep and 150 feet square contain two millions of gallons, sufficient for a daily supply for six months. The lakes and fish-ponds to be found in the grounds attached to almost all large mansions afford at once ready-made reservoirs, with a full available supply, if arrangements be provided for filtering the water. It is more than probable that many of these lakes and fish-ponds were originally devised by the abbots and monks belonging to the monastic institutions, who, in all such matters, showed a practical skill and forethought that has been too little imitated by those who succeeded them.

In flat alluvial districts, where the water in the outfall ditches is so near the surface of the land, as not to afford sufficient depth for the purification of the rainfall from the manure and other organic matter with which it would come in contact, and also on peaty soils, and in other similar cases where no suitable natural collecting grounds can be obtained, the difficulty may be overcome by constructing artificial collecting areas covered either with slates, concrete, asphalte, or other impermeable surfaces. The extent of these would, of course, be regulated by the rainfall of the district, nearly the whole of which might be relied upon. Mr. Easton has lately constructed at Ashton Court, in Somersetshire, a catchment area of concrete, covered with cement, half an acre in extent, with a tank for the supply of the mansion. His calculation is, that three-fourths of the rainfall will be stored, and that this ground will yield a supply of 500 gallons a day. When collecting grounds of this character are used, the size of the storage tanks will, of course, be very considerably reduced. As there would be no absorption, the rainfall of the summer months would be equally available with that which falls during the rest of the year, and the consequent decrease in the cost of the tank would go a long way to pay for the expense of the construction of the gathering ground.

WELLS.

The supply from wells, notwithstanding the fact that this source was considered by the Rivers Pollutions Commissioners as the most desirable, is not suited to the requirements of a rural population, when other sources are available. Shallow wells, whatever precautions may be taken, are always liable to the risk of contamination from sewage percolation. The water of deep wells is frequently hard, and unsuited for washing, for making beer, or tea, or similar domestic purposes. When this is the case, cottagers will always be found to avail themselves of a supply from a neighbouring brook or pond, even although it may be considerably polluted. The labour also of lifting water from a deep well will cause them to give the preference to the more easy means of supply. As an instance of this, it is stated that the inhabitants of the villages in Oxfordshire, where the water is obtained from deep wells in the chalk, rather than be at the trouble of undergoing the slow and laborious process of lifting it by hand, prefer taking their drinking water from the surface ponds, in which road drainage collects during rainy weather, and whence they can dip it with little labour.

SPRINGS.

In many localities there are springs within a moderate distance of a village, and at sufficient elevation to allow of the water being conveyed to the houses by gravitation. All that is required in this case is a small collecting tank at the head of the spring, iron pipes for conveying the water, and stand-pipes near the cottages. Numerous instances could be quoted where simple works of this description have been carried out either by private enterprise or by Rural Sanitary Authorities, the cost varying with the distance the water has to be brought, and the number of houses supplied. A typical case is given in the report of the Committee already referred to, of a supply for a village of 20 cottages with some better class houses, as rectory, farm houses, &c.; the spring being a quarter of a mile distant, the tank made to hold 1,200 gallons, the pipes of cast iron 1½ inches in diameter, the water supplied to the cottages by stand-pipes with keys, and to the other houses with half-inch galvanised iron pipes, the total cost £75. The interest on this at £6 per cent., and allowing for repairs, would make the charge one penny per week, to the cottagers, and four pence per week to the four other houses.

This is the simplest form of supply, where no easement has to be paid for the water, and the spring within a short distance. Taking the number of inhabitants at 120, the cost is only twelve shillings and sixpence per head. The average, however, may be taken at from £1 per head, or £5 10s. per house, under favourable circumstances, up to £3 per head, where water has to be paid for and lifted, or brought from a very considerable distance.

RAISING WATER BY MECHANICAL MEANS.

Where the source of supply is below the level of the village to be supplied, it is necessary to resort to mechanical means to raise the water. When there is an abundant supply, this is most economically done by means of a ram, but where the quantity is large a water-wheel and pump are found more efficient. The cost of a supply with a ram will depend on the quantity required and the length of piping. Mr. Hett, of Brigg, has furnished me with particulars of rams fixed by him for the supply of houses, and gardens, varying from £92 10s., with a lift of 200 feet and 1,800 feet of piping, and yielding 1,440 gallons in 24 hours, to £26 for 273 feet of piping, and 1,700 gallons. As rams force up a portion of the same water which actuates them, they are only suitable for use where the water is pure. Water-wheels, on the other hand, can be worked with any water that is available. Mr. Goslin (of the firm of Messrs. Warner & Co.) has furnished me with an instance of a water-wheel working treble-barrel pumps, for the supply of pure water, for a mansion, homestead, gardens, stables, &c., the motive power being sewage; and in another case where the water is taken from the lake and duck pond, to pump the pure water from a well. Of the wheels and pumps fixed by Mr. Hett, the cost varied from £76, for supplying 1,700 gallons a day through 1,200 feet of inch pipes, with 90 feet lift; the fall for working the wheel being 5 feet, to £133, for supplying 1,200 gallons through 1,600 feet of piping, with 165 feet lift. Mr. Clutton stated that the cost of fixing water-wheels eight feet in diameter, in the neighbourhood of the Cotswold Hills, for the supply of farm premises and cottages, was from £50 to £70.

In level districts, where no fall of water can be obtained, other means must be resorted to, and no more economical power can be used than wind. As nature has so admirably adapted her supplies of water to our wants in the case of the rainfall, so there is provided in the water or the wind a ready and effective power for lifting it up out of the underground storage reservoirs, the ingenuity of man only being required to apply the force in the most economical manner. Wind engines were formerly much used in the Fens for pumping the water off the land, but have now very generally been superseded by steam. Some few mills still, however, remain. They may frequently be found in this country in brick yards for pumping the water out of the pits, and are coming much into use for farm work. In America and the Colonies they are much more generally used than in England, many of the stations on the long lines of railway depending entirely on them for their supply of water; the irrigating channels on the rice fields being fed by the same means. A wind engine wastes no water, requires no fuel, and is economical in working; but as the wind cannot always be depended on, it must either be supplemented by horse or other power, or storage equal to at least a week's consumption provided. Mr. S. B. Goslin has furnished me with examples of several kinds erected by his firm. At Earlswood Asylum the water for the supply of 500 inmates has been raised by a wind engine erected several years ago. At St. John's Foundation Schools, near Leatherhead, the water is raised from a deep well to cisterns in the roof for the supply of 150 persons. A wind engine of their make also pumps the water from a well 200 feet deep for the supply of about 40 houses, cottages, and a mansion, at a cost, including pipes, of £263. At Portishead they also erected a wind engine and pumps for the supply of the village. Numerous other instances could be quoted, and it may be added that, at Margate, Faversham, Bridlington, and other places, windmills are used to pump a portion of the water supply, thus saving a considerable amount of fuel. I may also state that Messrs. Warner have lately erected, under my direction, a wind engine, for pumping sewage from a village for irrigation, and that Messrs. Hett are supplying a similar machine, supplemented by horse gear, for the sewerage works of a small town. The cost of both these engines, including pumps and fixing, was about the same, £100.

The use of the steam engine for the purpose of lifting water has not been dealt with, as being beyond the scope of the small class of works treated of in this paper; not so much from the first cost of the engines, which might not be more than those worked by either water or wind, but on account of the cost of attendance and maintenance. Wind and water are both self-acting, and require little attendance and no fuel, whereas steam engines require continual supervision and feeding; and this, together with the fuel and repairs, make the charges of maintenance so great as to preclude its use for small works, unless the engine be used for other purposes.

MEANS BY WHICH WORKS CAN BE PROVIDED AND COST DEFRAYED.

The duty of providing the supply and the necessary machinery must devolve either on the owners of the property or the Rural Sanitary Authority. A third course is where several owners have joined together and formed themselves into a company, under the Limited Liability Act. In the first and last case the works may be so carried out as to be remunerative. By the power of the Lands Improvement Act, of 1877, facilities are given to land owners of limited interest, with the consent of the Enclosure Commissioners, to borrow money and charge their estates with its repayment over a number of years for the construction of works necessary for water supply for their own estates or for villages. Also under the Enclosure Acts power is given to provide for the supply of water. Thus, in the enclosure of Coaley Common, works were carried out, consisting of a receiving tank to collect the water from a spring, and pipes laid to take the water to the village, with stand-pipes for its distribution, the cost, £750, being defrayed by a rate levied on the persons claiming under the enclosure of the Common.

The following may be quoted as some amongst many where landowners have themselves executed the works. In the evidence given before the Committee on River Conservancy, will be found a description of the works executed by Mr. McTurk for the supply of a village of 800 people, by laying down three miles of iron pipes connected with a reservoir, supplied by a spring, at a cost of £1,000. One hundred and twenty tenants used this water.

the charge varying from five shillings a year for a cottage to twenty shillings for a farmhouse. The total rental was £70, which was sufficient to pay five per cent. on the outlay and provide for a sinking fund.

The Prince of Wales, at Sandringham, has provided a complete system of supply for the house and the cottages on the estate. The water is conveyed from a spring, rising out of the chalk, through 750 yards of nine-inch earthenware pipes to the pumping station, where it is forced to a tank at the top of a tower 60 feet high, situate about a mile from the house. By this means ample pressure has been provided for the discharge of water over the house in case of fire.

The Duke of Bedford, at Thorney, has had works constructed for a complete water supply for the village, including the erection of an engine-house, with two 25 horse-power engines, tanks for holding 10,000 gallons of water, filtering beds, and other works. The engines are used also for pumping sewage for irrigation and other purposes. At Tavistock also, the Duke of Bedford has constructed reservoirs for collecting the spring water, and supplying it on the constant system to 751 houses at a cost of £700. The rate charged is 2½ per cent. on the rateable value of the houses.

On Lord Brownlow's estate, at Ashridge, a 28 horse-power engine, working three throw pumps, drawing water from a well in the chalk 255 feet deep, has been erected under the direction of Mr. Easton, C.E., for the supply of the mansion and farms, and villages adjacent. The total cost of these works was over £11,000, and the average amount of cost for repairs, attendance, &c., £430 a year.

The urban district of Bakewell, in Derbyshire, with 2,283 inhabitants, is supplied by water from works erected by the Duke of Rutland. Dunkeld, having 783 inhabitants, is supplied by pipes, bringing water from a burn in the hills, three miles away, laid down at the expense of the Duke of Athole.

Several instances of works carried out by the Rural Sanitary Authorities, for the supply of villages, will be found in the appendix to the report of the Select Committee of 1878, the cost being charged on the rates of the whole of each parish.

Where several owners are interested in providing the supply, the difficulty has been overcome by making use of the powers of the Limited Liability Act. Instances of this are given by Sir Harcourt Johnstone, as carried out on estates in which he is interested in Yorkshire. One company spent £1,040 for the supply of 500 persons, and another about £400 for the supply of 270 persons. The rental for the use of water is fixed at a sufficient rate to pay interest and maintenance of works, and averages about one shilling in the pound on the rateable value, or from 4s. 6d. to 5s. for a cottage.

Another case may be taken of Minehead, a small town with a population of 1,800. The total cost of the works was £3,400, or about £1 18s. per head. Numerous other similar instances will be found in the appendix to the sixth report of the Rivers Pollution Commissioners. This case is quoted to show the facility with which the water supply of small localities may be dealt with, where there is the desire on the part of the inhabitants to assist in carrying out sanitary work.

NECESSITY FOR REGULATING RIVERS AND MAINTAINING THE WATER LEVEL.

Before bringing this paper to a close, I wish to direct attention to a matter in connection with water supply which, in my opinion, is of vital importance. The disastrous floods of the last few years have raised a cry for improved drainage which, if not carefully watched, will lead to the drying up of our springs and wells, and cutting off the natural sources of supply. The maintenance of the underground water level has been too much lost sight of in this cry for thorough drainage. So far as the tidal influence extends, this will always be provided for. The inflowing volume of tidal water running up a river twice every 24 hours has a most powerful effect in checking the flow of the underground currents and consequent exhaustion of the storage reservoirs. The hydrostatic power of the high tide in fact drives the water in these subterranean channels back, so that there may be said to be a corresponding rise and fall of the underground streams coincident with that in the sea and tidal rivers. This influence extends for a considerable distance in land. In the great alluvial districts on the east coast, the subsoil of which consists of silt, a porous soil, through which water can easily flow, the wells are affected for several miles inland by the tides, the level of the water being higher in spring tides, and lower during neaps, so that it is invariably the practice to sink wells during neap tides. Again, on the west of these alluvial plains is a range of chalk hills and oolite formation, the water from which flows underground to the Wash. In the northern part of the plain, these streams are tapped at about 100 feet below the surface, and the water-level in the wells rises and falls with the tides in the ocean. The wells sunk along the high land known as the Cliff, extending from Grantham to Lincoln, which are from 100 to 150 feet deep, are affected by the state of the River Trent, which is 12 miles away, the River Witham intervening. The water commences to rise in these wells a very short time after the flood waters have risen in the Trent.

Beyond the influence of the tidal current, this underground water-level can only be maintained by holding up the water in the main streams and arterial drains. This can be accomplished either by fixed or moveable weirs, the streams thus becoming reservoirs, not only advantageous for preventing the over draining the water from wells and springs, but as providing storeage for the supply of houses and farmsteads, for affording motive power to machinery, and also for irrigating the land in the dry season. The immense impetus given to all mechanical work by the use of steam, has caused the more simple and natural agents of wind and water to be neglected. By one or other of these, the whole operation of pumping water, grinding meal, cutting chaff, thrashing corn, and other similar work, could, in many cases, be performed at a trifling outlay. The first cost of conveying water from a stream situated at a level above the farmstead by means of pipes, to a water wheel or other engine, would be less than that required for the purchase of a steam-engine, and the working cost afterwards wholly in favour of the water power.

Again, for irrigating and fertilising purposes, water is a most valuable agent, and far too little appreciated in this country. The large crops and high rents commanded by land in the Fens is due in a very great measure to the constant supply of water that is maintained during the summer in the drains, which holding up the water level, affords a supply of moisture to the roots of the growing crops. The whole level is intersected by large arterial cuts, or drains, the larger being of sufficient size to be navigable by barges; from these radiate small drains, and from these again the ditches which form the fences and boundaries of the fields. The larger drains, where they discharge into the tidal stream, are provided with sluices with self-acting doors available in floods, and also draw doors, which are put down directly the floods are over, the height being so regulated as to maintain the water at a fixed level, generally about three feet below the surface. The drains are supplied by feeders from the upland streams, which replace the waste from absorption and evaporation during summer. The extent to which this takes place may be gathered from the fact that in dry years no water at all passes out of the River Witham during the summer months, the doors for holding up the water being placed across the river, about eight miles above its point of discharge into the estuary. During the dry season of 1864, these doors were closed for several months, and it was not until the month of December that there was any flow of water down the river to the sea, although the Witham has a drainage area of more than eleven hundred square miles, and is fed by a large number of perennial streams.

It may be urged that, to hold up the water in our rivers and streams generally throughout the country would be prejudicial to health, and be the cause of disease and sickness. So far as the Fens are concerned, the contrary facts show the fallacy of any such idea. Previous to the enclosure of this tract of country, when water was lying stagnant in pools and morasses, and the sun acted on the decaying vegetation, fever and ague were generally prevalent. Since a complete system of drainage has been carried out, these diseases have entirely disapeared. Malaria is most intense immediately after water has left the surface of soil charged with decomposing organic matter. Hence the evil effects of occasional floods on land lying by the side of rivers. Intermittent fevers are engendered by alternate flooding and drying up of the meadows, but not by the constant presence of water. The Fen district having become drained and cultivated, the periodic inundations have ceased, and the organic matter has been assimilated by the constant process of cultivation, and forms the basis of the rich pastures and arable land. The large proportion of ozone in the Fen atmosphere, the physique and longevity of the inhabitants, and the small proportion of zymotic diseases, all testify to the healthiness of the district, and to the fact that holding up water in the arterial drains and water courses, while decidely beneficial to vegetation, is in no way injurious to health.

The experience gained in the drainage and water arrangements of the Fen districts may be usefully applied to other parts of the country. Our rivers should be made of sufficient capacity to carry off floods without damage to the surrounding land, and yet have their normal channels so regulated that the diminished quantity of the succeeding period of dry weather shall not have to meander hopelessly through a channel far too large for its requirements. The water level should also be so maintained, that the spring and underground reservoirs may be enabled to retain their stores and part with them only in such quantities that they may last out till replenished by the rain of the succeeding year; thus making the abundance of one season supply the deficiencies of another. It is not drainage or storage only that requires consideration, but both. They are not incompatible, but each may be provided efficiently by a proper regulation of the rivers and water-courses.

THE WATER SUPPLY OF LARGE TOWNS.

By the Rev. James C. Clutterbuck.

The "Notes on Previous Inquiries on Water Supply" invite remarks on the future as on the past. All water supply, whether surface or subterranean. whether naturally issuing from springs, or artificially reached by wells or shafts, is derived from rainfall; hence the value of the reports issued by the Meteorological Office, and the records of Mr. Symons and others, by which the amount and distribution of rainfall in various districts is determined. This natural supply cannot be augmented. and must, moreover, be estimated not on the average of years, but by a minimum which, year by year, is more heavily taxed to meet the wants of an increasing population, whose sanitary requirements require increased quantities, and purer qualities to be provided, and this not only for large towns, but for villages throughout the country, This is the problem which it is the object of this Congress to solve. The important question of water supply resolves itself into the economical use of quantities more or less ascertained. The metropolitan water supply, which from time to time is under discussion, is not only an important but an anxious subject of inquiry. Within the memory of men now living, the older parts of London, placed on a bed of gravel, resting on the clay, pierced by numerous wells, yielded a large amount of water. The sanitary requirements of the inhabitants has put a stop to the use of this source of supply. As late as 1834, it is stated in Telford's Report on the metropolitan supply, that the Grand Junction, West Middlesex, and Chelsea companies distributed only 6,810,000 gallons per diem, a quantity utterly insignificant as compared with the present quantity which these companies deliver.

The gradual depression of the water level in artesian or artesioid wells under London, has proved the impossibility of relying on that source for any increased supply; and may furnish a warning against trusting to artesian wells as a perennial source from such wells beyond the limits of the metropolis. The schemes for bringing water from the lake districts present difficulties not easily overcome. Not to enter into their consideration at length, yet, judging from the published reports, I am not aware that the perennial yield from these sources has been duly tested, by gauging the streams for a series of years, which issue from the lakes whence it is proposed to draw the supplies. The volume of the Thames, on the other hand, is well known, and as it derives the greater portion of its water from the chalk formation, almost from its source, there is no reason to believe that this, as a perennial supply will ever fail, though there is a yearly increased quantity taken by the towns on its banks. Though it may seem an insignificant quantity; in case of drought the consumption of water by railway, agricultural, and other engines is worthy of notice. The difficulties of the water question in nearly all large towns is too well known to require much to be said. Liverpool has failed to obtain a supply from deep wells; Manchester is to depend on Thirlmere. Other large towns, having exhausted their natural sources of supply, need to be warned that no sources are without a limit, and, as before stated, all quantities must be calculated on a minimum to be ascertained, not by an average rainfall, but by careful gauging of the streams which issue from the lakes, which are counted on as perennial reservoirs. The general supply to villages and smaller towns present many difficulties. It will be found that these, especially the most ancient, are placed on sites where water is, so to speak, at hand. Too often, through negligence or ignorance, these sources have been polluted and made unfit for use; this makes it difficult to find fresh and wholesome supplies, added to which, those persons appointed as sanitary inspectors seldom possess the knowledge necessary to determine questions of subterranean water. Though it must needs be attended with considerable expense to find duly qualified inspectors, this ought to be done to insure the knowledge of geology and engineering, indispensable in this matter. That there are many sources neglected which might be made available is beyond doubt; for example, Archdeacon Denison, as reported in a letter to the *Times*, secured for the village of East Brent, Somerset, a pure and abundant supply by intelligent observation, and at moderate expense. Other instances have come under my observation, but generally speaking the utilisation of the sources of water are beyond the powers of ordinary persons. A well qualified inspector might superintend a very large district, and, by advice and direction, secure supplies of water which had before been overlooked. This has frequently come under my own observation. A certain amount of geological knowledge is indispensable in this matter, and till such knowledge is duly brought to bear upon it, the question of water supply will not be duly understood or its difficulties solved.

PERVIOUS ROCKS OF ENGLAND AND WALES.

By C. E. De Rance, F.G.S., A.M. Inst., C.E.

(H. M. Geological Survey.)

In a communication the Committee did me the honour to bring before the Congress last year, I gave some statistics as to the extent of the chief geological formations, in 14 groups of river basins, into which I divided the 215 river basins of the Ordnance Survey Catchment Basin Map.

Since then I have made some further investigations as to the extent of the permeable and impermeable strata in each area, and also into the districts which receive underground drainage from other basins.

It will be noted that an important watershed crosses England diagonally from north-east to south-west, separating the basins of the Severn, Trent, &c., on the one side, from those of the Thames, east coast streams, Witham and Ouse on the other. This line nearly separates all the strata up to the top of the Trias, from the Lias upwards. Commencing on the chalk strata of the Isle of Purbeck, it ranges from Crewkerne, at the top of the Oolites across England, by Cheltenham and Chipping Campden, gradually resting on somewhat lower rocks. In advancing to the north-east, it passes over the Lias near Rugby, and reaches the Keuper marls at Gainsborough, where six square miles or so passes over the boundary, forming the only exposure east of that line. At Scarle, near Lincoln, and Burford, in Oxfordshire, the Trias has been reached and penetrated beneath the overlying Oolites, but south of the latter locality it probably thins out against the old palæozoic ridge underlying the Thames valley, connected with the Mendip range, which latter, though capped more or less by new red marls, was doubtless above water when the New Red Sandstone was deposited, and east of a line ranging through Gloucester and Stamford, the chance of the New Red or Permian being present in sufficient thickness to be water bearing, is very small.

In the Severn, and Avon basin, of the 1,831 square miles occupied by triassic strata, no less than 1,393 consist of red marls, much of which area is not suprapervious, resting on pretriassic impermeable rocks. The remaining 438 square miles of triassic sandstone absorb not less than 10 inches of rain annually, which is equal to a daily yield of 175 million gallons, or supply for 3½ million people at 50 gallons per head. The underground water of this basin will flow into the Trent basin between the north and south Staffordshire coalfields, in its northern area, and into the Thames basin in its southern area; but in the latter, from the southerly attenuation of the strata, this supply is of no practical importance.

South of the Mendip range in southern Somerset and Devon, triassic sandstones again come in beneath the marls, the former being 315 square miles in extent, and the latter 49 square miles. This area of sandstones, with 10 inch absorption, should yield a daily average of 126 million gallons, or supply for 2½ millions of persons, and is available for the supply of Exeter. In the valley of the Clywd, 40 square miles of triassic lower mottled sandstones occurs; it has been bored into to a depth of 600 feet, and rests on impermeable palæozoic rocks; it drains into the sea, beneath high water mark. In the Lancashire and Cheshire triassic plain, in the basins of the Dee, Mersey, and Ribble, occur 1,920 square miles of triassic rocks, of which 850 are red marls, for the most part salt-bearing, and of too great thickness to allow boring through to the sandstones beneath, which, however, crop to the surface over an area of 1,070 square miles, which, at 10 inch absorption, give a daily average yield of 428 million gallons, or a quantity sufficient for the supply of 8½ millions of people, at 50 gallons per head. The population of Lancashire and Cheshire, in 1871, was about two millions, so that the supply from this source alone is four times the demand. From these sandstones, more than six million gallons are pumped daily by the Liverpool Corporation wells off a very small area. Large supplies are also drawn for Runcorn, Widnes, Warrington, Stockport, Southport, Ormskirk, &c., water supplies. The underground drainage in the southern portion of this area is towards the Cheshire salt field, the top of the sandstone there being considerably beneath the sea level.

In the Tyne and Tees basin, 170 square miles of triassic rocks occur, about 100 miles being sandstone, and the remainder marl. The ground is low, and the permian limestone, with thick salt beds, occur below, and no good supply of triassic water can be relied on.

In the basin of the Ouse, Trent, and Humber occur 3,041 square miles of triassic rocks, of which 1,870 are marl (200 square miles around Charnwood Forest resting on the older rocks), and 1,171 red sandstones, which, at five inches absorption, would give a daily average of 234 million gallons, or a supply for 4⅓ million persons. The population of Yorkshire, Nottinghamshire, Derbyshire, and Staffordshire, in 1871, which are mainly in this area, was 5¾ millions. The demand is here in excess of the supply. In the West Yorkshire area it is met by a good supply of water from the elevated carboniferous tract forming the Pennine Chain. To the south a good supply is got from the Trias at Nottingham and other towns westward, but the supply is not satisfactory over a large part of the Staffordshire district.

As already stated, the diagonal watershed, passing across England from south-west to north-east, is situated mainly on the Oolitic strata. They only occur west of it in three areas, viz., 768 miles in the Severn and tributary basin, all of which drains underground into the Thames basin; 171 square miles in the Ancholme valley, draining naturally into the Humber; and 852 square miles in the Cleveland district of Yorkshire, of which 183 miles are north of the Trent basin, though the underground drainage flows into it.

The diagonal watershed nearly corresponds with the north-west boundary line of the counties of Lincoln, Rutland, Northampton, Oxford, Bucks, Wilts, and Dorset, the water falling on the Oolites in the basin of the Witham and Ouse of the first three of these counties, and Huntingdon and Bedford drains underground beneath the cretaceous rocks of Norfolk, Suffolk, and Herts, into the basin of the Thames and East coast. The watershed between the Thames and Ouse commences at a point on the diagonal watershed near Weedon, at the base of the Oolites; then it cuts across the strike of these rocks, passing over higher and higher beds until it ascends the chalk escarpment near Tring, where it travels north-eastward, and nearly follows the strike of the chalk, rising to an elevation of 500 ft. near Baldock, and, with somewhat diminished height forms, the central watershed of Norfolk and Suffolk.

The Oolites of the Thames basin occupy 940 square miles, those of the Witham and Ouse basin 3,701, those of the area lying west of the diagonal watershed 236 square miles, or a total area of 4,880 miles, the whole of the underground drainage of which gravitates to the Thames basin. Assuming that only one-third be pervious, or 1,626 square miles, and only five inches of rain annually to be absorbed, a daily yield will accrue of 325 million gallons, or a supply for six and a half million people. Probably, however, only a third of this amount can be obtained from the thinning of the Oolites under the overlying strata in the Thames valley, against the old Palæozoic ridge. The large yield obtainable is, however, proved by the great volume of the Thames head springs.

Of the 10,506 square miles of cretaceous rocks in England, only 1,329 miles occur west of the diagonal watershed, 999 being in Yorkshire in the Trent and Humber basin, 16 miles on the west of the line, but draining underground into the Thames, and 257 miles in South Devon, forming the Blackdown beds. In the Thames and east coast district not less than 4,000 square miles of pervious cretaceous rocks, receiving not less than five inches of rain annually, or a daily supply of 800 million gallons, it is readily understood with these figures how the dry weather flow of the Thames is kept up, by chalk springs, this yield is sufficient for 16 million people; and taking the Oolite supply, the total volume of water yielded by underground sources in the Thames and East Coast river basins may be taken at 1,125 million gallons, a supply equal to the wants of 22 million people, or nearly that of the total inhabitants of England.

The cretaceous rocks occupy 2,038 square miles in the Witham and Ouse basins, about 1,500 square miles being pervious. Those of the Humber and Trent basin have already been described.

The tertiary deposits are chiefly impermeable; they occur entirely east of the diagonal watershed, and occupy 3,333 square miles in the Thames and East Coast basins; they are everywhere suprapervious, resting on the cretaceous rocks, now being bored into at their base by the New River and other companies, and long drawn on by the London brewers.

ON THE UNDERGROUND WATER-SUPPLY OF VILLAGES, HAMLETS, AND COUNTRY PARISHES OF THE CENTRAL AND EASTERN COUNTIES OF ENGLAND.

By Professor Edward Hull, LL.D., F.R.S.,

Director of the Geological Survey of Ireland.

That the development of zymotic diseases in villages and rural parishes is due to "dirt," which, as Lord Palmerston defined it, is "matter in the wrong place," and also to bad water, is an axiom that is accepted as soon as stated. Few, however, except those whose lives are passed in such localities, are aware to how large an extent these preventible diseases are prevalent, even in places where beneficent Nature has granted all the necessary aids to health. The stagnant pool, the pestilential manure heap, the odoriferous ditch, are but too frequently the immediate surroundings of a cottage or farmstead: and in the midst of these, or near thereto, is often planted the pump for the water-supply of the household, which, with the purer underground waters drawn from wider areas, again brings to the surface some proportion of the percolating filth.

On the other hand, where the geological condiions permit, many villages and hamlets are upplied with water from perennial fountains or leep wells; which, drawing their waters from wide areas of strata, through which the rainfall has percolated by the natural process, have thereby become uited for use. In the early planting of these slands, such fountains were generally selected as he sites of hamlets or homesteads, and many of hese remain to the present day, along the borders of the chalk, the lower Greensand, and the Oolites; while, within the area of the London basin—as Prof. Prestwich has pointed out—many of the uburban villages near the city of London were grouped around a spring of water, or bed of gravel, rom which water could easily be drawn by shallow wells.[*]

Before entering further upon the subject of this ommunication, I wish to premise that I have no ntention of dealing with the question of water-upply to large towns, or any of those places which would come under the head of "Urban Sanitary Districts" of the Public Health Act of 1872. Such districts and towns may well be relegated to the are of their respective sanitary authorities, guided by a corps of engineers, who are ever ready to find water if only the money for the purpose is forthcoming. It is to the more humble and greatly neglected villages, hamlets, and country parishes of the central and eastern counties my observations are intended to apply, with a view of showing hat the means are generally available for providing hem, where required, with that essential concomiant to health, decency and comfort—good water.

Physical Considerations.

Though large portions of those districts of England referred to in this paper are destitute of hills—the birth places of springs and fountains—yet it happens that the geological formations are arranged so as to constitute underground reservoirs or a large proportion of the ordinary rainfall, which can be rendered available by wells of greater or less depth. These districts are composed of the mesozoic or secondary formations, consisting of alternating beds of permeable, or water-bearing, and impermeable, or dry, strata; generally arranged with such a moderate dip as to spread over arge areas; and capable of retaining, on the one hand, or throwing off, on the other, a certain proportion of the rainfall, varying in amount according to circumstances.

The water-bearing strata consist of sandstones and limestones of various kinds; the impermeable, or non-water bearing, of clays and shales; and it is herefore evident that any system of water-supply applicable in the one case would not be so in he other. Accordingly, the subject divides itself nto two heads, viz., supply by means of wells, and upply by means of artificial reservoirs or tanks.

The capabilities of the mesozoic (or secondary) ormations from the chalk to the new red sandstone inclusive, for furnishing permanent supplies of pure water, are being energetically investigated by the Committee of the British Association, "for nvestigating the circulation of underground waters," of which Mr. De Rance, F.G.S., is the Reporter. Four valuable reports have now been issued, and the investigations of the Committee originally restricted to the New Red Sandstone and Permian formations, have, since 1877, been extended to the Jurassic or Oolitic formations.

In the report for 1878, reference is made to the Congress on Water Supply held by the Society of Arts, and Mr. De Rance quotes his estimate of the areas of the formations yielding underground waters which he laid before that Congress, and which are as follows:—

	Square miles.
Permian and Trias (New Red Sandstone)	8,645
Oolite limestone, &c.	6,671
Hastings sand (Wealden) Greensand and chalk	11,371
In all . .	26,371

He states that probably four-fifths of the area of permeable rocks would yield, were they tapped, unpolluted water, and would receive into their mass not less than from ten to fifteen inches of rain water annually; a quantity which, if only six inches in depth were drawn from wells, would yield no less than 240,000 gallons per day for each square mile of surface, and which would be far in excess of the requirements of the population.[*]

This is no doubt a theoretically correct estimate, and although the available supplies may be far below it, enough has been said to show that the underground reservoirs are of vast extent and resources.

f.) Permeable (or Water-bearing) and Impermeable (or Dry) Formations.

So much has already been written upon the nature of these formations, and the qualities of the waters they are capable of yielding, that I shall content myself with a very brief description of them; commencing with the chalk formation downwards (see Table on next page).

Out of the twelve sets of strata, arranged in the table according to their water-bearing qualities, there are seven which are permeable, viz.:—(1) Chalk and upper Greensand, (3) lower Greensand, (4) Purbeck and Portland beds, (6) Coral rag and grit, (8) Oolites and upper Lias sands, (10) middle Lias, (12) New Red Sandstone, with a total thickness varying from 1,275 to 5,500 feet, while there are alternating with the above five sets of strata, which are impermeable, viz., (2) Gault clay, (5) Kimmeridge clay, (7) Oxford clay, (9) upper Lias clay, (11) lower Lias and Keuper marls, with a total thickness varying from 2,110 to 5,430 feet vertical.[†]

(2.) Qualities of the Waters from the Permeable Strata.

In endeavouring to ascertain the qualities of the underground waters derived from different formations, it may be generally assumed that those drawn from limestone formations are "hard," and those from sandstone "soft." Owing, however

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[*] Anniv. Address, Geol. Soc. Lond., 1872.

[*] Reports, p. 2.

[†] I have purposely omitted the clays and gravels of the drift series, as they are of so variable a nature that no general rule can be laid down regarding their water-bearing qualities. The boulder clay is, however, a generally impermeable stratum, and the middle sands and gravels water-bearing; from these springs good soft water often issues forth.

GEOLOGICAL FORMATIONS OF THE CENTRAL AND SOUTH-EAST COUNTIES.

	Formations.	Permeable Strata.	Impermeable Strata.	Quality of Water.
		Thickness in feet.	Thickness in feet.	
1	Chalk	645 to 1,000	..	Hard
	Upper green-sand	100 to 400	..	Rather hard.
2	Gault clay.......	..	130 to 200	..
3	Lower green-sand[*]	20 to 500	..	Soft and good.
4	Purbeck and Portland beds	0 to 60	..	Rather hard ?
5	Kimmeridge Clay	..	300 to 600	..
6	Coral rag and grit	40	..	Rather hard.
7	Oxford clay....	..	350 to 500	..
8	Great and Inferior oolites	200 to 450	..	Hard.
	Upper lias sands	20 to 200	..	Soft ? ;
9	Upper lias clay..	..	30 to 300	..
10	Marlstone or middle lias	30 to 250	..	Rather hard ?
11	Lower lias clay	..	500 to 600	..
	Keuper marls (trias)[†]	..	600 to 3,000	Gen'ly imper.
12	Lower keuper sandstone[‡]	150 to 450	..	Soft.
	Newred sandstone (Bunter)[§]	0 to 2,150	..	Soft or variable
13	Lower permian beds (alternating characters	Variable	Variable	Soft.

to variations in the nature of some of the strata in different localities, and to the greater or less proportion of carbonate of lime, carbonate of magnesia, or salts of iron, &c., which they contain, the quality of the water from the same formation is liable to variation, according to locality. This subject has already been so fully dealt with by various authors, that I do not consider it necessary to do more than give a brief summary of the results, as far as they have been ascertained, in several localities.

(*a*.)—WATER FROM THE CHALK.

From analyses of many wells and springs in this formation in the South-east of England, it is well-known that "chalk water" is hard, though clear and well suited for many purposes, especially in the important one of brewing. The percolation of the rain through this formation, amounting to about one-third of the actual rainfall, is so exceedingly slow, that the water has abundant time to take up a large proportion of carbonate of lime from the rock itself. The mode of percolation has been ably treated by Professor Prestwich,[*] Mr. Clutterbuck,[†] Mr. Homersham, C.E.,[‡] and others. It seems, from observations made on the chalk hills by Mr. Beardmore,[§] that it takes from four to six months for the rain to reach a depth of 200 to 300 feet, so that the water which is drawn from this depth in summer belongs to the rainfall of the preceding winter. The total quantity of solid matter in chalk water varies from 31 to 32½ in .100,000 parts, of which from 16·4 to 21 parts are of carbonate of lime. In the case of large works, this mineral ingredient can be dealt with by the softening process invented by Dr. Clarke; but for country villages, there seems to be no plan of easy application for lessening the amount of calcareous matter, except that of boiling, by which the hardness is reduced from 24·7 to 3·7 in extreme cases.

(*b*.)—UPPER GREENSAND.

The water from the upper Greensand is probably a little less hard than that from the chalk.

c.—LOWER GREENSAND.

The water from this formation is generally considered unexceptionable, and decidedly "soft." Samples taken from five localities, give a mean result of 7·9 of solid matter in 100,000 parts of water. Mr. Bateman, C.E.[‖] speaks of the water from this formation in the basin of the Wey as being of the greatest purity; and as the sands are generally loose and incoherent, they absorb nearly all the rain which falls on their surface, except that given off by evaporation, or imbibed by vegetation.

Enormous quantities of water are absorbed by this formation, where, as in Surrey and Kent, it is largely developed, and to such an extent are they capable of being rendered available, that Mr. Lucas proposes by means of tunnelling, to render them useful for the supply of London.[¶] In Bedfordshire, Bucks, and Berks, as also in the S.W. of England, the formation attains large proportions, and contains bands of siliceous iron ore, which to some extent affects the water. Exposure to the air, however, causes the iron to be precipitated.

d.—OOLITE LIMESTONES.

The waters from these formations are more or less hard, yet less so than those from the chalk, and of course, where the source is the sandy strata which accompany the limestones of the Portland Oolite, the great and inferior Oolites, &c., the qualities of the water will be found to vary accordingly. Of the proportion of solid matter in the waters of the Oolites, that found in the fine springs of South Cerney, near Cirencester, which rise along the line of a large fault, may be taken as a sample. The total amount of solid matter was found to be 18 grains per gallon, of which 1·25 was of organic origin.[**] The water from the Seven Springs near Cheltenham, from the inferior Oolite, gave six grains per gallon, of which two grains consisted of organic matters.* The well at Thames Head, pumping from the great Oolite near Cirencester, gave 16 grains per gallon; † and the waters of the Chelt, above Charlton Mill, near Cheltenham, which rise from springs at the base of the inferior Oolite, gave 20 grains per gallon, of which four grains consisted of organic matter.

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[*] The lower Greensand of Surrey consists of several members of varying hydrometric qualities, for an account of which see "Geology of the Straits of Dover," by W. Topley, F.G.S.; and "Horizontal Wells," by W. Lucas, p. 21.

[†] The beds of Keuper sandstone about the centre of the marls often contain water. In the Scarle boring, a feeder of water yielding 11 gallons per minute was struck in these beds at a depth of 790 feet.

[‡] In Scarle boring about 250 feet thick.

[§] Scarle, 540 feet.

[*] Anniversary Address, 1872, p. 41.

[†] Proc. Inst. Civ. Engineers, 1842-3 and 1850.

[‡] Report Royal Commission on Water Supply, 1869.

[§] *Ibid.*, p. 204.

[‖] Report contained in a Return to an order of the House of Lords, 1852, No. 268.

[¶] Horizontal Wells, by J. Lucas, F.G.S. (1874).

[**] Analysis, by J. Horsley, F.C.S., appended to Report on the water supply of Cheltenham, by Dr. Wright, F.R.S.

(e.)—New Red Sandstone.

Next to the chalk, the New Red Sandstone—ncluding the Bunter and Lower Keuper divisions—is the most important water-bearing formation n the district under consideration, and the water which it yields possesses this advantage over that of the chalk, that it is softer, and generally capable of being used for all domestic and manufacturing purposes. From the numerous analyses that have been made of these waters in different localities, n the central and N.W. counties, we have the means of arriving at general conclusions on this subject; and for special and accurate details, we may look forward with interest to the Reports of the Committee on Underground Waters, appointed by the British Association in 1874.‡ The beds of the Bunter sandstone are wonderfully adapted to act both as natural filters and as reservoirs for that portion of the rain which sinks below the surface. This may be assumed at one-third of the actual rainfall as an average; while in some districts—where the formation consists of soft sandstone, or unconsolidated conglomerate, devoid of a thick covering of drift clay—the amount of absorption must reach well nigh one-half the amount of rainfall. Owing, also, to its uniformity n composition, and the absence of beds of clay or marl of any importance, the whole mass of rock below a certain level, and throughout a depth of several hundred feet in some districts, becomes water-logged; and wells sunk therein do not (as n the case of the chalk) generally depend for their supply on the presence of fissures, but water is nearly always found after the "water-level" of the immediate district has been reached.

The remarkable permeability of this formation, equalling, probably, that of the lower Greensand both of England and France, has recently been illustrated by the deep boring in search of coal at Scarle, near Lincoln. This boring, conducted by the "Diamond Boring Company," was commenced in the lower Lias in 1874, and, after having passed through 790 feet of these beds, and the underlying impermeable marls of the Keuper, struck a feeder of water in the lower Keuper sandstone, and a still stronger one at 950 feet, which caused the water to spout up 5 feet above the surface. The whole of the Bunter sandstone below was also charged with water, as proved by the increasing temperature down to its base of 1,500 feet from the surface. Now, the distance of this boring from the outcrop of the beds towards Mansfield, varies from 12 to 16 miles, and through this distance the water percolated from a district 300 or 400 feet above the sea-level, till it reached a depth of about 900 feet below it; and, being kept down by the overlying impervious beds of Keuper marl, ascended to the surface with great force on the artesian principle, on being released, through means of the bore-hole.*

The amount of solid matter per gallon in the waters of the new red sandstone varies from six to fifteen grains, where they have been taken from wells not too shallow, or from those which are free from contamination by sewage pollution or other causes. It is to such a cause that the large proportion of saline and other ingredients in some of the Liverpool and Manchester wells, amounting in some instances to 24 and 36 grains per gallon respectively, is attributable. In general, the proportion of these ingredients occupies a central position between those of the chalk and other limestone formations on the one hand, and the surface waters of mountain districts, composed of millstone grit or of silurian rocks, on the other. The following examples will probably be considered sufficient for the purpose here intended:—

	Wells or springs.	Grains per gallon.
Liverpool district† ..	Bootle	24·00
,, ..	Soho	24·80
,, ..	Windsor	23·22
,, ..	Green-lane	13.60
Birmingham‡ ..	Aston	12·82
Stourbridge§ ..	Well of W. W. Co. ..	21·95
Leek (Staffordshire)‖	Wall Grange Spring ..	12·26
Whitmore (nr. Crewe)¶	Well of London and North-Western Ry.	6·10
Parkside (near Warrington)** ..	Well	11·12
Nottingham ..	Several wells (suburban) ..	12·0 to 16·0

As an illustration of the effect of the percolation of saline matters on the waters of even deep wells in large towns, I give here the analysis of the waters of a well from the south side of Manchester, made in 1865 by Dr. Angus Smith, F.R.S. This will show the desirability of having all wells, as far as possible, removed from such sources of contamination:—

Water from Well, Manchester, South Side.

	Grains per Gallon.
Cloride of sodium	4·88
Sulphate of soda	7·33
Carbonate of soda	7·35
,, of lime	9·77
,, of magnesia	5·29
Phosphoric acid, potash	traces.
	34·65

Lithia discovered by spectroscope.

This permeability is likewise exemplified by the condition of the Liverpool wells. There can be no doubt, from the observations recently made, that the saline ingredients are increasing in the

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[*] Horsley's Analysis. See, also, Prof. Prestwich, "On the Geological Conditions affecting the Water Supply of Houses, &c." (Parker and Co., Oxford), 1876.

[†] Horsley's Analysis, Sup. Cit. p. 8.

[‡] Belfast Meeting. First Report presented at Bristol, 1875.

[*] From information kindly afforded by Mr. J. T. Boot, mining engineer. Proc. Inst. C.E., vol. xlix., p. 1.

[†] Analysis by Richard Phillips, F.C.S.

[‡] Analysis by Dr. Hill, F.C.S.

[§] Supplied by Mr. E. Bindon Marten. This well is only 46 feet deep.

[‖] Analysis by R. Phillips.

[¶] This well supplies the works and populace of Crewe, and was sunk, on the recommendation of the author, by the London and North-Western Railway Company, 1864.

[**] Analysis by Dugald Campbell, F.C.S.

waters of the wells, and that much of this water is derived by infiltration from the estuary of the Mersey. It is only on such grounds that the extraordinary supplies derived from these wells can be satisfactorily explained. This proves the desirability of having the wells sunk a good distance from the sea; and I venture to suggest that the plain of Cheshire, lying south of the Mersey, and so far as it is formed of New Red Sandstone, offers a source of supply as yet but slightly drawn upon.

On the other hand, the purity of the waters from the Aston well, the Wall Grange spring (yielding 3,000,000 gallons per day), the Whitmore, Parkside, and Nottingham wells—where removed from the influence of populous neighbourhoods—must be considered as completely establishing the excellence of this source of water supply.

Considering, therefore, the wide extension of the water-bearing strata of the New Red Sandstone, the excellence of the formation as a source of pure water—equally cool and refreshing in summer and winter—it must be conceded that the central counties are happily situated as regards their prospects of water supply, provided these resources are judiciously utilised. Nor must it be forgotten that the internal reservoirs do not terminate with the upper boundary of the Sandstone, but that the waters pass for great distances under the overlying impervious marls, as illustrated by the case of the Scarle boring, and that by deep wells or borings these underground reservoirs may be converted into perennial fountains.

(3.) Application of the above Observations to the cases of Villages and Hamlets.

From what has been stated, it will be obvious that for those villages, hamlets, or parishes situated on any of these water-bearing strata, or not far from their upper margins, where they pass below the overlying impermeable formations, wells are the proper and available means of supply. But the determination of the question regarding the character of the formation underlying each special village or hamlet, as well as the selection of the best site for a well, are, evidently geological questions, requiring some special knowledge of this branch of science; and the problem how such knowledge is to become available in each case remains for solution. To this I now address myself.

In the first place, as admitted by Mr. Edwin Chadwick, C.B., the completion of the maps of the Government Geological Survey, over the districts comprised in this paper, places them in a very advantageous position for availing themselves of the underground waters stored up in the strata. Until some accurate and detailed maps, such as these were, rendered available, the data for arriving at definite conclusions regarding the geological situation of many localities, could not be obtained. With these maps, a Sanitary Board ought to be able, with very little assistance of a technical kind, to determine whether a particular village or hamlet requiring good water, was so placed, geologically, as to be able to obtain a supply by means of a well; and, if so, also the best spot in which such a well should be sunk.

I am aware, however, of the unhappy and prevalent ignorance of even the most rudimentary principles of geology amongst such bodies, and it would, therefore, be necessary, for the proper carrying out of the proposals here suggested, that an experienced geologist should be attached to the staff of the Central Board of Health in London, whose duty it should be, when applied to, to afford advice in all cases of this kind. Owing, therefore, to the progress of the Survey over the districts here alluded to, it seems to me that the time has arrived for putting in force some scheme of general application, depending on geological considerations.

(4.)—Cases not admitting of Supply by means of Wells.

I now come to the case of those villages, hamlets, or parishes, which, owing to their geological position, cannot be supplied by means of wells. These are they which are situated on such impermeable strata as the Oxford clay, the Lias, or the Keuper marls; or are at such a distance from the subjacent water-bearing strata, that the depth of a well would be great, and the expense too costly for the resources of the inhabitants. In such cases, a supply from surface drainage of some available brook or rivulet seems the only resource; and powers should be given by the local sanitary authority to impound such streams in small reservoirs or tanks, under proper and stringent regulations, so as to prevent surface pollution of the water, either in the stream or in the reservoirs. The construction of such small reservoirs as would be necessary for the purposes here alluded to, would entail only a moderate amount of engineering skill and of pecuniary outlay. In providing pure water it would also be necessary to stop up or destroy all impure wells, pools, or tanks, in the same village or hamlet, as the poor are very apt to prefer a source of supply to which they have all along been accustomed.*

(5.)—Machinery for Carrying out a General System of Water Supply for Villages and Hamlets.

We come now to the difficult question as to the machinery for carrying out such a system of water supply as is here proposed; and perhaps the first step to be taken is to ascertain to what extent the evil of insufficient or polluted water supply prevails in country places. This, I think, might be effected by means of the agency evoked under the Public Health Act of 1872. Under the clauses of that Act, the rural sanitary authorities have the power of appointing a medical officer of health and an inspector of nuisances for a period of five years; and it would probably not be difficult, by their co-operation to obtain returns from all the parishes included in the rural sanitary districts, together with the villages and hamlets contained therein. I would propose that a simple form of circular be drawn up by, the authority of the Local Government Board, which the officers above named should be required to fill up and return, stating—1st. The names of the villages or hamlets in each rural sanitary district; 2nd. The number of houses; 3rd. The existing mode of water supply; 4th. The opinion of the medical officers regarding the nature and quality of such water, if any there be; and, 5th. Observations regarding the general health of the inhabitants and the presence of zymotic diseases. It would then be the duty of the Local Government Board to eliminate the names of those villages or hamlets in which it would appear, from such returns, that the water supply was sufficient, both as regards quantity and quality; and then would remain those residuary cases, requiring to be dealt with under the scheme here proposed. They would probably be found to amount to several hundreds within the limits of the area dealt with in this paper.

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* Such power is granted to the Local Sanitary Authority under the Act of 1872.

It would doubtless be advisable, in carrying out such a scheme, that the existing Parliamentary powers should be called into requisition. After perusing the Public Health Act of 1872, it seems to me that, with slight modification, that Act might be made available. The division of the whole country into (1) urban and (2) rural sanitary districts is excellent, and at once determines the districts outside and within the scope of the proposals I have ventured to offer. The appointment of medical officers of health by the sanitary authorities, but who are responsible to the central authority in London, offers an effective agency. Under Clause 17, the rural sanitary authority has power to provide a supply of water for rural sanitary districts; but such districts are, I fear, too extensive for such modes of water supply as is here proposed, and it would be necessary to split them up into villages and hamlets, having independent powers, though the necessary expense might be spread over each district.

I would, therefore, propose that, when it is found from the reports obtained through the rural sanitary officers, that the supply of water to any village or hamlet is insufficient or impure, the sanitary authority of the district in which the village or hamlet is situated should be required to proceed forthwith to apply the remedy. It would be necessary then, in the manner I have ventured to suggest, to ascertain whether the locality could be supplied by a well, and if the local technical acquirements are insufficient to settle this question, the aid of such a Government officer as has been already referred to should be afforded; while at the same time it should be competent for the sanitary authority to call in professional advice from any other quarter.

A well having been determined upon when the geological conditions prove favourable, the site fixed with reference to local circumstances, and the cost having been ascertained, powers should be granted to raise money for carrying out the work and rendering the well available for the free use of the whole of the inhabitants.

In sinking such a well, the top waters, to a depth of 10 or 12 feet, should always be carefully stopped off by solid masonry or hydraulic cement; and means be adopted for keeping it free from contamination, under stringent regulations and heavy penalties. Being for the use and benefit of all, it should be jealously guarded by all as as a public benefactor.

I have not considered it necessary to enter at length into the means by which my proposals should be carried out. These are matters of detail, capable of settlement by those who are conversant with such matters. I have contented myself with sketching out a plan of general application which will probably be considered sufficient for the present occasion.

By one or other of the above methods probably all the villages or hamlets of the central and eastern counties which require it might be supplied with pure water. Till this is done, it cannot be considered that we have reached the state of sanitary improvement befitting a great and prosperous country.

WATERSHED LINES.

SUBTERRANEAN WATER-RIDGES.

By Joseph Lucas, F.G.S.

The surface-ridge which forms the western boundary of the basin of the Medway in the chalk area, marks also the position of the subterranean water-shed line from Cobham as far south as Meopham-green, a distance of four miles. The surface boundary ridge continues its south-westerly direction for another three miles to the chalk escarpment, near Wrotham; but the subterranean water-shed ridge takes a south-easterly direction at Meopham-green, and runs under a valley, and then by a slight curve along the course of the ridge through David-street, Harvel, and Sparrow Haugh, to the chalk escarpment in Down's Wood, one mile and a-half east of the point at which the surface boundary ridge reaches the escarpment. The subterranean drainage of the included triangle (physically within the Medway basin) flows towards the north-west, under the apparent boundary ridge, and then north to the Thames at Gravesend. The area thus lost to the Medway basin is rather over one square mile and a quarter.

From the point (south of Fairseat) at which the above-named surface boundary ridge strikes the chalk escarpment, there starts also the eastern boundary ridge of the so-called basin of the Darent. This ridge runs almost due north, through the heart of the chalk country, as far as Longfield-hill, a distance of four and a-half miles, after which it runs in a north-westerly direction to near Dartford, a distance of six miles, the last four being over tertiary strata. Unlike the last, this ridge, although inclosing the Darent basin, as viewed by the modellist, does not in any part of its course mark a subterranean water-shed line. On the contrary, it traverses longitudinally, at a small angle, an immense depression in the surface of the chalk water system, which forms the subterranean basin next adjacent to that of the Medway. This is the Stansted basin, which empties itself into the Thames near Gravesend.

The Stansted basin is bounded on the west by a broad ridge, under which there also lies a strong subterranean water-shed line. The chalk water system in this block of hills, between the Medway and the Darent, attains its greatest altitude at the southern extremity of this ridge, near Terry's Lodge Farm. The subterranean water-ridge can be traced north for four miles, or as far as Hartley, when it gradually disappears by the convergence of the Stansted basin and that to the west, or the Fawkham basin. The western boundary of the

Fawkham basin is the surface-ridge running through Kingsdown, Chimhams, and Speed Gate, and thence towards the village of Darenth. A subterranean water-ridge accompanies this, without exactly coinciding with it, as far north as Horton Kirby, a distance of four and a-half miles, when it, too, becomes indistinct. This water-ridge forms the true eastern boundary of the Darent basin—the Stansted and Fawkham basins taking the waters of an area of 17 square miles from the apparent basin of the Darent under the surface ridge to the Thames direct.

The western boundary of the Darent basin, and, therefore, the eastern boundary of that of the Cray, is a remarkable line. There are few lines in nature so straight. The subterranean water-ridge runs almost absolutely straight for 11 miles. It corresponds generally in position with the surface-ridge, the following exceptions being noteworthy.

Where the surface-ridge runs along Well-hill, the outlier of tertiary strata, by cutting off direct access of rain to the chalk water system, throws the subterranean water-shed a little to the west. Again, from Crockenhill, the surface boundary ridge runs north by a curved course over tertiary strata, round by Joyden's wood. Since this mass of tertiary strata also cuts off the direct access of rain to the springs, the chalk water-ridge does not partake of the curve, but lies to the east, under Hextable and Oakgreen, Wilmington—the greatest divergence being one mile. The included area of nearly two square miles, therefore, drains into the Cray basin.

The western boundary of the Cray basin in the chalk area, and therefore the eastern boundary of the Ravensbourne basin, follows the surface-ridge from Holwood as far south as Cudham-lodge, south of which I have no good evidence as to its course. I incline, however, to think that it does not follow the surface ridge to the south-east, but more probably continues a south-westerly course, to the chalk escarpment, north of Limpsfield. If, after a closer survey, this should prove to be the case, the area of the included triangle, three and a-half square miles, will have to be subtracted from the basin of the Ravensbourne, and given to that of the Cray.

The western boundary ridge of the Ravensbourne basin in the chalk, runs south from the tertiary Addington hills, along a spur and an outlier of Thanet sand, by Selsdon and Sanderstead, having there a south-westerly direction. The subterranean water-ridge lies between them, having a south-easterly course. The surface ridge curves round to the west, but the subterranean water-ridge keeps its course by Kingswood-lodge and Kennel Farm, falling in with the surface-ridge at Worms Heath, whence they appear to run together to the escarpment. The included area is about a square mile and three-quarters. This feeds the Wandle basin, whose eastern boundary is thus described as far north as Selsdon, from which place it takes a north-westerly course—the surface-ridge along the tertiary strata, and the subterranean water-ridge outside by West Croham. Along the western boundary of the Wandle chalk basin, the surface and subterranean lines correspond generally nearly the whole way from Sutton to the chalk escarpment. North of Banstead, the water-ridge lies rather to the west of the surface-ridge, and south of that place, a little to the east of the surface-ridge, which runs along tertiary outliers.

The Mole basin takes the drainage of the tertiary strata for a distance of seven miles measured along their base—four miles west and three east of Leatherhead, but it does not take any contributions direct from the chalk along the same line, the basin being fan-shaped and having its apex at Leatherhead. The area dispossessed on the east side is two and three-quarters square miles, and on the west side the same. These areas drain under the tertiaries. The subterranean water-ridge on the west side does not correspond with any surface-ridge, but lies north-west of that running down to Leatherhead, until it crosses it near Effingham-hill, after which it runs parallel to, and half a mile east of, the western boundary ridge of the basin, to the escarpment.

The Wey basin takes the drainage of 12 miles of tertiary strata, measured along their base, five west and seven east of Guildford; but the Wey at Guildford takes the drainage of a fan-shaped area of chalk country, not more than three-quarters of a square mile in extent, the drainage of the chalk range east and west passing under and over the tertiaries. The Wey basin also takes the drainage of the chalk from the western end of the Hog's-back to Dippenhall, west of Farnham, a distance of about four miles and a half.

In the chalk area of Hampshire, the basin of the Wey, as measured by the surface-ridge, is larger by twenty-eight and a half square miles than it is as measured by the boundaries of the subterranean water-ridge.

The subterranean water-ridge corresponds generally with the surface-ridge separating the basin of the Wey from that of the Loddon, as far as about one mile north-east of Shaldon. The surface-ridge then turns north-west, a direction which it holds for eight miles. Only the first three and a half of these are between the Wey and the Loddon. At Herriard, the boundary-ridge of the Wey basin branches south-west for five miles, and then turns due east for two miles to Medsted. The water-ridge, however, instead of following it round this course, runs straight across through Shaldon to Bentworth, whence a branch water-ridge between the Loddon and the Itchen runs north-west. The area thus cut off drains into the Loddon basin, and is four and a half square miles in extent. From Benthworth another branch of the water-ridge runs south to Medsted, cutting off a second area of 2¼ square miles, which drains into the basin of the Itchen. From Medsted, where the two ridges coincide, the surface ridge takes a southerly course, somewhat sinuous through Chalwood and Privet by Froxfield to the chalk escarpment at Stoner Hill. The subterranean water-ridge, however, strikes nearly straight across by a south-easterly course from Medsted to Nore Hill. At Farringdon it passes under a large valley, into which it occasionally rises, bursting about the out-crop of the lower chalk as a bourne which flows down the valley to Alton. In all the ramifying system of easterly sloping dry valleys above Farringdon, the water falls towards the west under the surface boundary ridge, and into the basin of the Itchen. The area thus cut off is 21¾ square miles, making a total of 28½ square miles to be subtracted from the basin of the Wey in the chalk of Hampshire.

The water-ridge dividing the basin of the Loddon from those of the Itchen and the Test, lies to the south-west of the surface ridge, preserving a distance of about a mile and a half from it, from near Bradley, through Nutley, to Church Oakley, where it crosses the South-Western Railway. East of the railway, the Loddon basin receives the subterranean drainage of about nine square miles of chalk country, lying physically within the basins of the Itchen and the Test.

The southern boundary ridge of the Itchen basin marks the subterranean water ridge for, at least, four miles east of Millbarrow Down; the first two miles separating the Itchen from the Hamble, and the other two from the River Meon. East of West Meon the surface ridge probably also generally marks the subterranean water-ridge; but, if so, there must be a rapid northerly fall from it in the extreme south-eastern portion of the Itchen basin, in which the subterranean water is 50 feet lower than the River Meon at East Meon. The southern surface boundary ridge of the Meon basin lies a little to the south of the subterranean water-ridge, whose summit rises into the valleys on the northern slope of the hills, so as to cause springs, permanent tributaries of the Meon, high up those valleys, and within a mile of the ridge, whereas on the south side of the hill there are no springs nearer than the tertiary base, four miles south of the ridge. This is owing to the lower chalk outcropping on the north side of the hill, and the upper chalk forming the southern slope. The area thus lost to the Meon is about a square mile and a-half.

TABLE SHOWING THE APPARENT AND REAL AREAS OF CHALK COUNTRY LYING WITHIN THE WATERSHEDS OF THE SEVERAL BASINS NAMED.

	Apparent Chalk Area.			Area proved to drain elsewhere.			Mean daily loss to apparent area at 6ins. absorbed per annum.	Extraneous Areas proved to contribute.			Real Chalk Area.
	Square Miles.			Square Miles.			Gallons.	Square Miles.			Sq. Mls.
	West side.	East side.	Total.	West side.	East side.	Total.		West side.	East side.	Total.	
*Medway	22½	..	..	1¼	..	..	281,063	..	..	..	..
*Gravesend	..	..	40	..	..	..	..	17	1¼	18¼	58¼
Darent	23¼	41	64¼	2	17	19	4,522,020	..	..	..	45¼
Cray	..	..	26½	..	..	..	..	3½ (?)	2	5½ (?)	32
Ravensbourne	..	..	21	1¾	3½ (?)	5¼ (?)	..	..	..	..	15¾ (?)
Wandle	..	..	52½	..	..	..	..	..	1¾	1¾	54¼
Hogsmill River, &c.	..	..	13	..	..	..	..	..	..	..	..
Mole	14	9	23	2¾	2¾	5½	1,309,006	..	..	..	17½
Wey, Surrey	7½	11 }	58	..	..	..	..	..	..	..	..
,, Hants	39½	.. }		28½	..	28½	6,783,086	..	..	..	11
Loddon	..	..	83	..	..	..	..	9	4½	13½	96½
Itchen	..	..	148½	..	..	..	..	..	24	..	..
Hamble	..	..	12	..	..	..	..	..	..	..	..
Meon	..	..	31½	..	1½	..	357,000	..	..	..	30

*South-west of a line drawn through Gravesend and Strood.

NATIONAL WATER SUPPLY.

By Joseph Prestwich, F.R.S.,

Professor of Geology in the University of Oxford.

I much regret that my engagements here will prevent me from being present at the Conference on Thursday and Friday next. I do not, however, know that I have anything to add to the communication I made last year on the subject of "Water Supply." It is one to which, on geological considerations, I feel much interested, while its importance on sanitary considerations cannot be over-estimated.

It is not only the purest springs and rivers that have to be sought, but it must also be borne in mind that the protection of springs from pollution is equally essential as that of rivers, and is even more difficult to guard against. If I may be allowed, I will quote the concluding paragraph of a lecture I had occasion to give before the University of Oxford, three years since, on this very subject, in which some of the dangers of our present system are pointed out, and the necessity of the steps the Society of Arts is now taking is alluded to.*

"The importance of a large and good supply of water cannot be over-rated. This, as a general proposition, is now fully understood, and in all our large and populous towns able engineers have constructed works to secure such supplies, and to do away with the abuses that were inevitable where, as formerly, each house was the centre of its own water supply and drainage. But, although the flagrant sources of contamination are generally removed from our large towns, they still too often lurk in hidden or forgotten corners, while in the hundreds of smaller towns and villages, and in thousands of country houses, the plague-spot still exists in almost all its foulness and intensity. The air may be pure, the country may be smiling, the waters may be bright, the people may be cleanly, ease and luxury may prevail on the surface, but below that surface a poison is, by a delicacy which is not unnatural, hidden out of sight, unknown to most, often kept in subjection for years, or working so insidiously as to raise no suspicion; but there it is ready, when the opportunity offers, to fix on its prey, and to spread disease and death around; the blow, in fact, is often so covertly given, that neither the sufferer nor his friends suspect when or whence it comes. The great outbreaks are exceptional. They unavoidably attract attention. But it is a question with me whether the sum of the minor resultant evils does not outbalance the more prominent cases. Against these many risks it seems nobody's business to guard.

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* "On the Geological Conditions affecting the Water Supply to Houses and Towns, with Special Reference to the Modes of supplying Oxford." Parker and Co., Oxford. 1876.

"The evil is so widespread and so deep-rooted that I apprehend nothing less than legislative action will be able to effect a cure, and protect an unwitting population from conditions over which they, in general, have no control, and of which, without special inquiry, they cannot possibly have any knowledge."

I am truly glad that this great question—which is one of primary national importance—has been taken up by the Society of Arts, and sincerely trust it may attract the attention and support it deserves.

RIVER CONSERVANCY.

By Professor D. T. Ansted, M.A., F.R.S.

The Bill brought into Parliament by the Duke of Richmond, on River Conservancy, and already passed by the House of Lords, seems to show that this important subject is at length seriously considered, with a view to legislation either in the present or an early session. There are points worthy of consideration concerning the objects attainable by proper conservation of streams, and the duties of conservators, that may fitly be discussed at the present Congress.

One of the first of such points is to determine the grounds on which rivers, or groups of rivers, may be best brought into combination for purposes of conservancy. A division of our country into natural and convenient groups of catchment areas of moderate extent is essential for this purpose, and must be generally admitted as a preliminary step. The offer of the Council of the Society to give medals for useful suggestions to this effect can hardly fail to result in some agreement on the subject.

Assuming that some system of grouping is agreed on, and that the whole country is parcelled out into a moderate number of conservancy districts, the next point is to determine the objects of conservancy. We may take for granted that any recognised mode of grouping catchment areas must include, among primary districts, the basins of our great rivers. The basin of the Thames and that of the Severn, the basins of the Trent and the Yorkshire Ouse, and probably the basins of the Great Ouse, the Mersey, and the Ribble, would be regarded as requiring, in each case, a separate staff. There are certain conditions of rivers, common to all these, that will enable us to point out fairly enough the requirements of conservancy, and the matters that need consideration on the part of Conservators.

These requirements will certainly include the following very distinct subjects, concerning each of which supervision is needed on behalf of the public:—

(1.) *Navigation.*—Under this head must be understood the conservation of all the navigable portion of a main stream and its tributaries, and the improvement of the river in this respect when desirable. For this purpose the banks of an open river must at least be retained without deterioration; in most cases they will need improvement. In canalised rivers the whole system of lockage as well as the banks must be kept in good order. In every case, the bottom must be dredged, if the scour is not sufficient to remove the mud that would otherwise accumulate.

(2.) *Sanitation.*—By this must be understood the conservation of the waters of a stream from its source downwards, and of all tributaries, in such a state of purity as shall not injure the health of persons inhabiting the banks of the stream, whether collected in villages or large towns.

(3.) *Fisheries.*—To a certain extent this is concurrent with sanitation; but it becomes a separate subject, and one of primary importance, when the natural food-supply is large and valuable, and there is but a small population of any kind on the banks of the stream, and no urban population whatever.

(4.) *Prevention of Flooding.*—This interest, which in certain rivers and tributaries is paramount, requires close attention to the banks of the stream throughout, the construction of works, perhaps in the upper part of the stream, perhaps near the point where flooding usually takes place, and the maintenance of such works as exist. Where flooding is occasionally inevitable, owing to the physical conditions of the whole catchment area, provision requires to be made to direct the flood, so that it will do as little damage as possible to towns and other inhabited places on the river course.

(5.) *Treatment of Fen-lands.*—In the case of certain rivers which flow over wide tracts of low-lying lands near the mouth, and reach the sea at a level little above low water, the rivers are, in many cases, tortuous, and have no fall for a long distance. To assist the flow by shortening the river channel, and, where necessary, lift the water to a higher level to enable it to reach the sea, have involved the construction of great engineering works, which it is the duty of river Conservators to superintend and keep in order. On the performance of these duties depends the safety of large populations, and the preservation of extensive tracts of land in a cultivable state.

But to carry out properly the systems of drainage in these cases, requires constant attention to the upper parts of the stream and its tributaries, which also becomes the duty of Conservators.

(6.) *Water-power.*—In most streams, the water-power of rivers is utilised in some parts of its course, and the interests of the mill-owners, as well as the rights of the public, where the power is still unused, should be the subject of careful consideration in river conservancy.

Such being the requirements of well-known and important rivers in reference to conservancy, it will be evident that, whatever the districts may be that are ultimately decided on, there will need, on the part of the public officials appointed, much special and technical knowledge, in addition to the general intelligence they may be presumed to possess, and this special knowledge must have a tolerably wide range.

It is quite conceivable that, if the Conservators of a district should be persons chiefly interested in navigation, the sanitation might suffer, or that too absolute a devotion to the sanitation or the fisheries, might result in serious obstruction to navigation. So, also, the measures taken to prevent flooding at certain important points. might interfere with the ultimate delivery of the water from the uplands to the sea, especially in tidal streams, or too rapid a delivery of the waters of a river into a wide extent of flat lands near its mouth, might swamp and injure lands brought and kept under cultivation at great cost.

There cannot be a doubt, also, that rapid and thorough deep drainage of the whole of a catchment area, carrying off the rain quickly to the valleys, and thence to the main stream will not only sensibly alter the whole conditions of agriculture and pasturage, but affect the quantity of water delivered by streams, the times at which the water of feeders is delivered into the main stream and the quality of the water. River conservancy is needed to regulate these results.

In addition to these possibilities, it may be observed that embankments constructed near the outflow of rivers are liable to impede the progress of fish up stream at spawning time, unless care is taken to assist them by mechanical contrivances, to overcome these obstacles.

The constitution of a Conservancy Board for rivers will, therefore, be imperfect, and the Board will be unable to perform its task with intelligence and usefulness, if its members consist exclusively of persons whose monetary interest in land within the district conserved, or in house or other property on the river banks, is their only or chief qualification.

Such persons, however intelligent, could hardly be expected to decide fairly as to the nature and cost of works it might be desirable to undertake, the bearing of such works on those of similar nature already completed, or their influence, perhaps remote, but none the less certain or important, on the future state of the river. The composition of Boards of Conservancy is a matter of great national importance, and requires the introduction of some element other than mere property.

The Conservators of each river basin, or group of catchments, united under one Board, will have special duties, according to the physical condition of the district taken in hand. In each case, some one or more interests will be paramount, and to these the others must, to some extent give way, but they must not be neglected.

One of the first necessities in every district placed under the control of a Board, will be the construction of a contour map of the whole basin. Such a map has been prepared by the Ordnance Survey for the Thames basin, and it is believed that the facts ascertained by the Survey are sufficient to provide a similar map for every district. A careful study of such a map will be the best introduction to the duties of each Board.

It is desirable that the employment of rivers for any special purpose should not interfere with the proper and legitimate use of the stream for other purposes. All the dwellers on the shores of a river, as well as all riparian owners, have an inalienable right to receive the water that comes down a natural channel, derived from natural sources, in a serviceable and uninjured state, and each person may use it as it passes his property, provided it is returned to the stream. This right cannot be got rid of without the interference of Parliament, and to enforce the law in this, and secure justice to all who are interested, the action of some public body is necessary, for it is generally the case of the poor against the wealthy and powerful. The conservators of a river system or district should be instructed to regard the preservation of public and private rights as a sacred duty, and should be empowered to act on behalf of the public.

It may, and does happen, that the rainfall naturally falling on the catchment area of a river system may, in part, or even entirely, be better employed, so far as the whole nation is concerned, in providing a water supply for one or more large towns, than for the dwellers on the banks, or the riparian owners. If it is so, the private right must give way to the public need, although in such case full compensation should be given. If only a part of the water is taken, and the water is chiefly employed as motive power, artificial reservoirs may be constructed, the storm waters otherwise running to waste may be impounded, and water compensation given by sending down the stream daily a fair average of the water. In other cases, money compensation may be given. In discussing and settling disputed questions of this kind, an efficient Board of Conservators might, with advantage, give a decision, and prevent litigation.

There are instances in which the channel of a river or tributary has been used for many years as a drain or common sewer, to carry away the waste of manufacturers, and there are other cases in which the water of streams has been fouled by washing or cleansing operations necessary for carrying on important works. When the waters thus injured are feeders of streams which afterwards pass towns and other inhabited places, it may be necessary to prohibit such uses of the water; but great judgment is needed in so doing, for it may be possible to check and divert important sources of national wealth, by interfering with, and rendering unprofitable, staple manufactures in districts in which they have been long carried on.

For purposes of navigation in a river, it has already been mentioned that the removal of accumulations of mud from the bottom is essential, such accumulations being in most cases inevitable. The removal must be effected by dredging, but the selection of a place for the deposit of what is thus removed may need careful consideration.

It may be utilised in the formation of banks, or for raising banks already in existence, and may thus prevent flood; or it may be required to raise permanently the level of the valley in certain parts, or raise adjacent low-lands liable to flooding. On the other hand, it may be desirable to leave certain low lands of little value unprotected, so as to permit flood waters to enter and remain for a time, and thus avoid serious inundation in other parts of the stream. To decide on such matters should be among the duties of the Board of Conservancy.

The duties of conservators in regard to sanitation are very serious. Theoretically, and according to the belief of some authorities, every objectionable material allowed to enter any part of a stream, renders all the waters below suspicious, Practically, we know that no river in existence could be other than a mass of poisonous corruption if this were true, and that on the contrary, almost all streams, except where the quantity of water is small and the pollution excessive, pass down after a short flow in a clear and apparently pure stream.

There can, however, be no doubt that when manufactures are carried on on a large scale, and where high cultivation and heavy manuring are carried on in lands already deep-drained, a large quantity of polluted matter may pass into the stream. It cannot be denied that this is a source of danger. It might be expected that the large steady increase of population (about two millions in each successive ten years for many decades past) should act in the same direction, and cause increased pollution, but this is counteracted by the tendency of the population to increase in the towns at a rate higher than that of the natural ratio of increase of the whole population, and also by the fact that the precautions now generally insisted on will probably ensure the purification of effluent sewage waters coming from towns. It should be the duty of river conservators to decide what is safe and sufficient purification of this sewage effluent, and take care that no injury to health shall befal any river under their superintendence by neglect of proper precautions.

It has been pointed out that the question of sanitation must in one sense include that of fisheries. If the waters of a stream are fit for human use, they will not be improved for the benefit of the fishes; and, on the other hand, where fish live and multiply, the water is not likely to be in a very unfit state for men. Many rivers and tributaries, however, coming from the hills in a state of extreme purity, and crowded with fishes, receive at certain points the waste of, or are otherwise fouled by, manufactures which destroy the fish. Where the volume of water is increased by large additions in a pure state, and the matter thrown in is not deleterious, or is purified by oxidation on its way to the main stream or the sea, or when the stream is small and passes no town or place where its waters are needed for domestic purposes, it may be a question whether the manufacture is to be sacrificed to the fisheries. In deciding this question, which is one certain to come before them, Conservancy Boards will need to exercise great judgment.

To prevent a river, when in heavy flood, from so expanding at certain points of its course, as to avoid injury to towns or important manufacturing or other interests near its banks, has always been regarded as one of the chief objects of river conservancy, and is so recognised in the Act now before Parliament. The injury from flooding is not only very serious as regards property, but it extends to human life, and, if possible, should be prevented at any cost. The works, however, that must be constructed to check this mischief require great engineering skill to plan; they require that the whole history of the river and each tributary should be carefully studied, and that the meteorology and geology of the whole catchment should be as well known as the physical geography. In the Thames basin, where the interests are largest, the construction of the basin renders this reference to the whole physical condition more necessary than in any other in England, but in almost every division of the country that could be suggested complications are sure to arise with reference to the times, places, and possible amount of flooding, that need constant attention to these physical conditions. It is not desirable that any Board of Conservators should be appointed without members qualified to recognise the importance of considerations of this kind.

Boards of river conservancy appointed to manage the Great Ouse, the Welland, the Nen, and the Witham, draining the Fen country, and emptying into the Wash, have to deal with a tract involving special and recognised difficulties, and provided already with numerous engineering works, which have been constructed, or in course of construction, during a long period, and are provided with engineers to carry out the requisite operations. The duties of the conservators, however, in this and other cases of special kind. should extend over the whole of the river basins concerned, and enable them to watch over and influence the outfall by controlling the rivers from their sources. There can be little doubt that in this way much might be done to diminish the risk that sometimes arises in very wet seasons.

With regard to the large tracts affected by this group of rivers, and others that enter the sea over similar few lands, it is well known that their inhabitants are liable to fever, ague, and rheumatism. It is no doubt true that these special diseases of fen districts have been checked and modified by improvements in drainage, but there is still much to be done in this respect, and it can only be done by combined action over large districts, and with the aid of constituted authorities.

The remarks I have ventured to offer on the duties of river conservators I wish to be regarded as suggestions for discussion, rather than as an attempt to embrace the whole subject. It has occurred to me that, in the preparation of the Bill now before Parliament, both the powers to be granted, and the duties to be performed, by the Boards have been insufficiently considered, and that, under these circumstances, a discussion as to these matters might bear useful fruit. It may not be too late now to introduce clauses into the Bill in Committee, and should this Bill not pass during the Session, the way will thus be opened for a more complete and better-considered measure hereafter. It is not likely that our rivers and river basins will continue to be neglected as they have hitherto been.

The conservancy of rivers very directly affects the question of water supply to towns. That rivers must always be, as they have always been, the most valuable sources of supply for general purposes is inevitable, and that in many cases due care has not been taken to preserve them from pollution is equally certain. In such cases, instead of sources of health they may become the means of introducing disease. Under the care of properly-selected conservators, empowered to act, and required to enforce the law against all who infringe it, there is no reason why every river in the kingdom should not be utilised in a reasonable way for power for manufacturers, and for the use of towns, and after all this be sent down to the sea in such a state as to do no harm to the human inhabitants on the banks, or to any fishery that the density of the human population will allow to exist near its outfall.

SUPPLY AND STORAGE OF PURE DRINKING WATER, EAST BRENT, SOMERSET.

By the Ven. Archdeacon G. A. Denison.

I have much pleasure in complying with your request, that I should send you some brief account of what has been done for storage and supply of pure drinking water at East Brent, lying at the foot of Brent Knoll, Somerset.

Twelve years ago there was no such supply, except to a very limited extent, for the village of East Brent, with its large vicarage house. The sources of such supply were also at a considerable distance from the houses. Now, the water rises by natural pressure to the top of the vicarage house, and is brought within a little distance from every house in the village, in some cases into houses by branch pipes. The supply is also unfailing and overflowing. I have been nearly 34 years at East Brent. There had been always water for the vicarage house, but with supply failing in very dry weather, and only at command by means of a force pump.

In the 34 years there have been three years of epidemic disease. I found that in all three cases, the disease came in years of drought, and after drought. The account of this is simple. The inhabitants generally draw their water from the same ditches which carry the sewage. In time of drought the amount of sewage bore a proportion to the water running or standing in them so large, as to poison the whole of it; whereas, in time of larger fall of rain, the poisonous effect was, so to speak, neutralised.

All these things, and indications of a choked spring a little way up the knoll, led me to begin the experiment of spring tracing and reservoir making. The result has been the discovery of the old mill of Glastonbury time, and, as I believe, of hundreds of years before 1180, the present date ascertained; two springs of excellent water, never failing, and of the formation of several reservoirs containing together a large supply of mixed spring and surface water. It is to be noted that, as there are no houses on the knoll, the supply of surface water, at times very large indeed, is as pure as can be had. But the two springs being more than sufficient for the use of vicarage house and village, I am drawing all supply from them, shutting off the reservoir water, which in a rainfall, becomes clouded for some days, and insuring a constant supply of pure and unclouded water. I have, however, reserved command over the reservoir water, in case that, in excessive drought, the springs should fall too low. The reservoirs fall at varying heights, the higher into the lower, by overflow or tap, or syphon; the entire fall from the upper end, of the highest reservoir, to the door of the vicarage house, being some 50 feet. They make excellent pools for trout and other fish.

Having thus been enabled to supply the vicarage house and village of East Brent, I am very desirous, if the means can be provided, of supplying, out of the great quantity of water, which might be had by further means of storage, and developing of springs, the villages round the knoll, and first of all, a hamlet of my own parish, about 1½ miles away. That this might easily be done, and at a cost which, relatively to the benefit to be insured, would be very small, it is impossible for me, with all my experience of the locality, to doubt. But it is a thing quite beyond my own means, and one which ought to be taken in hand publicly. At present, the district is in the position of having abundance of pure water offered to its hand, but of refusing to stretch out its hand to take it. The knoll is a great natural reservoir. It presents great natural advantages for storage of surface water. It is full of springs. All that is wanted is to develop and apply. As the matter now is, I know of no worse instance of neglect of a great natural gift.

I shall be happy to receive at East Brent, any one interested in supply of water, and to show him what has been done, and how much more might be done.

Since writing the above, I have received this morning, May 10th, from an able analyst the report following:—"Both your springs are remarkably free from organic impurity, and admirably adapted to drinking uses."

ON THE EFFECTS OF UNDER AND ARTERIAL DRAINAGE ON RIVER FLOODS.

By James Dillon,

Vice-President, Institute C.E., Ireland.

The pollution of rivers, the silting up of their beds, and the damage caused by river floods. renders legislation on the subject necessary, and this applies not alone to England, but to the United Kingdom.

True it is that great progress has been made with the removal of river floods in Ireland, but further legislation is required, and if certain alterations were made in the Act 26th and 27th Vic., and the Acts amending same, under which river works are carried out in Ireland, I have reason to believe that an Act for England, drawn on nearly the same basis, would enable all the principal rivers to be successfully dealt with, whereas, if these amendments are not made, matters must soon come to a dead lock in both countries; for this reason it is to be hoped that final legislation on this subject may extend to the whole of the United Kingdom.

Having charge of several river works in Ireland, I would wish first to state that, confining the floods in the upper reaches of a river valley within the river banks, instead of allowing the floods to spread over the banks, has not had the effect of increasing the floods to such an extent as to cause an increase in the damage done by the same floods in the lower reaches of the same valley below the termination of the upper works; and even admitting for the moment that theoretically, drainage works may have increased river floods, still it has been found impracticable to measure or value the damage, if any, caused thereby.

Careful records have been kept of the River

Shannon floods in Ireland, before and after the floods, from some of its tributary districts were confined within their river banks, where formerly the floods were allowed to cover the land.

The engineer to the Board of Public Works, Ireland, Mr. William Forsyth (lately resigned), a man of great ability and sound judgment, and who had more to do with the river works in Ireland up to 1863 than any other man, in a report on the subject, dated 13th April, states:—That although eighteen tributary, or sub-districts, having their outfall in the River Shannon, have been relieved of their floods, the daily registries of the depths of waters on the Lock Sills along the lower reaches of the Shannon, below the 18 districts, show that the discharge in a given time has not been materially increased by relieving the lands in the 18 districts from their flood waters. In the same report, Mr. Forsyth states, that the late Mr. James M. Rendel, C.E., of London, said it was established that all flooded lands within a rain basin, and sending their surplus waters to be carried off by the same main outfall river, have contributed to the cost of improving the common outfall, while they respectively managed the drainage of their own sub-districts independently.

The Earl of Rosse, in 1871, stated before a public meeting, held to promote the River Barrow improvement, that the drainage of a large flooded district above his demesne at Parsonstown, had not had the effect of increasing the volume of floods passing through his demesne to any appreciable extent, although engineers predicted that bridges would be carried away, and the demesne of Parsonstown flooded more than it had been.

Mr. R. Rawlinson, when giving his evidence in 1877, before the Lords Committee on Conservancy Boards, was asked, had the extension of drainage works very much increased the suddenness and violence of floods, answered, "I do not believe that either drainage or cultivation effect floods in any appreciable degree." (See page 21 of the Minutes of Evidence.)

Other eminent men expressed a contrary opinion, but I am not aware that they caused any measurments to be made of the volume of floods before and after the execution of works for confining said floods within the river banks. Having successfully treated several districts in Ireland for protection from floods and for drainage, I was asked by the late Duke of Leinster and others in 1871, to report upon the effect of under drainage on river floods, and having made certain observations, and carefully considered the matter, the substance of my report was that the former had no appreciable effect on the latter. This led to my being asked to report by different landed proprietors, upon the proposed River Barrow drainage, embracing some 625 square miles of a river basin, and finding the various interests so conflicting, I was forced to abandon the idea of carrying the work out as a whole, the cost of which would exceed some £300,000.

I pointed out the great advantages to be derived from carrying out the works in sub-districts under the superintendence of Local Boards acquainted with the localities with which their interests were connected. Accordingly, I was directed to proceed with the carrying out of two of the sub-districts. I at once met with great opposition, on the ground that I would flood the lower valleys, but I proved to my opponents I would not, and I am now completing both sub-districts successfully without increasing the destructive effects of the floods lower down the valley.

I believe few engineers have had the opportunity of recording the volume of river floods before and after the execution of works for confining them within their river banks.

The following is the substance of the results I have arrived at in the case of the Upper Inney River Works. These works extend over 82 miles of rivers and tributaries; the catchment basin or area of country discharging its waters into this system of rivers extends over 278 square miles, and its centre is situated about 53 miles to the west of Dublin, at a level of 211 feet above the sea, the rock formation being limestone.

The whole of the river works were designed so as to carry off about four feet below the surface of land, the flood waters which formerly saturated and covered with water 12,260 statute acres of land, equal to seven per cent. of the catchment basin. During the progress of the works, it was necessary to carry out extensive rock, gravel, and other excavations, and to rebuild 60 bridges, the total cost of which amounts to about £60,000.

The works under my charge were commenced near Lough Iron, at the point where the Lower Inney Works, carried out under the direction of the Drainage Commissioners of Ireland, were suspended on account of their excessive cost and want of funds to proceed further up country.

Previous to the commencement of the Upper Inney drainage works, the average summer discharge in the river from the upper district amounted to ·0689 cubic feet per acre per minute, and the average flood discharge to ·4896 cubic feet per acre per minute. After the execution of the works, the average summer discharge at the same place amounted to ·0827 cubic feet per acre per minute, the flood discharge to ·4827 cubic feet per acre per minute. Almost similar results have been obtained by me in other districts.

In the paper I read before the British Association last year, I endeavoured to point out why such results should be expected, and as I hope to continue my observations in connection with several other works I have now in hand, I may hereafter be able to throw some new light on this interesting and important question.

There is no doubt that since the publication of the facts and papers above referred to, many men of great intelligence have admitted to me that, after careful observation of the floods below the different new river works, they were beginning to think that the views I entertain on the subject are very nearly right, namely, that although under drainage may slightly increase the volume of floods in winter from the uplands, still, by providing a suitable channel of sufficient capacity through a somewhat flat river valley, that it has the effect of equalising the flood discharges through the same by drawing off at the commencement of the floods from the inner portion of the river basin (before the floods from the more distant portion of the same basin reaches them), some of that flood water which before the execution of the works would have covered the river valley, and which, if left there, would have prolonged the duration of the floods, when passing from the surface of the valley to the lower reaches of same valley, while at the same time under drainage does certainly increase the summer flow by gradually drawing off the water, which would otherwise escape by evaporation in summer, when most required for use.

Mr. Denton, when giving his evidence before the Lords' Committee, in 1877, above referred to, is represented to have estimated the extent of land systematically under-drained in England and Wales at 3,300,000 acres, or, approximately, about one-twelfth of the surface of England and Wales; as some of this drainage is likely to be very imperfect this may fairly be considered an over-estimate. It is known that most river basins are composed of a very undulating surface, embracing hills and sometimes mountains, so that the flood waters are in constant motion over the same. If, therefore, the flood volumes from eleven-twelfths of the basins in England continue to reach their river valleys in the same volumes and at the same rate in 1879 as they did 300 years ago, the eleven-twelfths not being under-drained, how can it be possible, admitting for the moment that there may be a small increase, theoretically speaking, in the floods from the one-twelfth of drained land, that such a slight increase from one-twelfth of the surface of England and Wales could increase, to any appreciable degree, the eleven-twelfths of the unaltered flood volume from land not under-drained.

Again, I believe it will be generally admitted that there is but a small fractional quantity of the surface of each river basin actually covered with water in flood time. The average proportion of land covered by the floods in river valleys in Ireland does not exceed four and one-fifth per cent. of the entire river basin, and as the surface line of these floods have all more or less a considerable declivity, the whole of the floods from the 95 per cent. of the river basins must continue to flow into the river valleys at the same rate before and after the execution of any works in these valleys, so also must they continue to flow out of these valleys, on account of their declivity, for it is, I believe, admitted by the majority of engineers, that there is but a small fractional portion of river floods actually covering the surface of the lands compared with the large volumes rushing down the rivers. It is, I think, unfortunate that so many men of eminence still hold to the opinion that the destructive effects of modern floods are, to any appreciable extent, due to the extension of under-drainage.

What I fear is, that hasty legislation, based upon this latter theory, will become so unpopular, should it give the power to any constituted body to tax the dry up-lands on the side of a mountain in one county, for the benefit of reclaiming flooded lands in another county, that such legislating must ultimately retard rather than promote the formation of Conservancy Boards throughout the country, having for their object the proper regulation of the rivers, particularly as eleven-twelfths of the land in England has not been under-drained, and, therefore, has not contributed to the increase of floods.

It would be easy to point out the different causes all contributing to raise the flood levels in certain districts throughout the country, although the flood volumes may not have been increased to any appreciable degree.

We know, however, that most river valleys are being gradually filled up now, as well as in former times, and that under these circumstances the multiplication of new fixed and permanent obstructions throughout these valleys renders the formation of some central governing authority necessary to check a further development of such evils.

Having endeavoured to prove that the increasing destructive effects of river floods are not due to the under-drainage of one-twelfth of England, but more to the increase of towns and artificial obstructions in the river valleys. I will pass on to the second part of this paper.

ON THE INCIDENCE OF RATING, &c.

It was generally admitted, until very recently, that no mountain, hill, or other dry up-lands in a river basin in one county could be taxed for the drainage of lands in another county; there may no doubt have been exceptional cases more calculated to prove the rule than otherwise, but I understand that in England, in the great majority of cases, the tax for river improvements has been limited to the lands proposed to be benefited by drainage or relieved from floods as the case may be. I am, however, in a position to speak with more accuracy as to the universal law on this subject in Ireland, as I have much to do with defining the boundaries and regulating the tax of several of the districts in which river works are now being carried out under my direction. The law in Ireland, down to the present time, is that no lands can be taxed for river works unless damaged by saturation or river floods, therefore it is only the damaged lands that practically constitute the district and pay for the improvement works. Previous to 1842, no river work could be formed unless the owners of two-thirds of this damaged land assented to a drainage district being formed under the central Board sitting in Dublin. (See Drainage Acts passed for Ireland in 1842-45-46 and 48.) The 9th Vic., cap. 4, reduced the assents required from two-thirds to one-half, as it was found impracticable to obtain assents amounting two two-thirds.

Under this amended Act, 266,736 statute acres were relieved from the effect of floods at a cost of £2,390,612, but the works proved so costly, and the Act became so unpopular, that in 1853 the Treasury in London intimated that they would make no further advances, and accordingly no new works were sanctioned, another proof that central Boards are not suitable for the carrying out of very large districts.

Then, in 1863, owing to previous agitation in and out of Parliament, the Government sanctioned a general drainage Act being passed for Ireland, authorising private parties to form drainage districts (see Act 26 and 27 Vict., c. 88, and Acts passed amending same), provided that two-thirds in value of the injured land are owned by parties assenting to the project, and if the two-thirds petition, the Government will grant the necessary money to carry out the works, if satisfied with the financial prospects of the undertaking.

The progress of arterial drainage works in Ireland, under 26 and 27 Vict., c. 88, from July 31, 1863, was as follows:—Under this Act the works for 37 districts have been sanctioned, and are now nearly completed. Their effect has been to drain and free from floods not less than 71,000 statute acres, at a cost of £389,000, equal to an average outlay of not less than £5 9s. per acre, as compared with £7 per acre under the 5th and 6th Vict." Notwithstanding that the above results as regards Ireland are so far satisfactory, still it is a fact that year by year such works are becoming most difficult of accomplishment, owing to the impossibility of adjusting the conflicting interests of the upland and lowland proprietors. If the lowland proprietors promote a scheme for the improvement of the larger and consequently more costly sections of the rivers, they generally try to tax the upland proprietors (owning flooded lands) for works that can confer no benefit upon them, while if the upland proprietors try to improve their smaller and less costly rivers, they are opposed by the lowland proprietors, who erroneously contend that their floods are made worse by the drainage of the uplands, &c.

The extent to which these supposed conflicting interests interfere with the carrying out of such works may be judged from the fact that the Board of Public Works, in Ireland, in their report for 1877-78, announce that from Ireland last year there was only one application for a new drainage district, so that unless subsequent legislation proves more successful, there will be few, if any, useful works of this class carried out when those already sanctioned are completed.

One great defect in the Act of 1863 was requiring assents to a work amounting to two-thirds, when it was known that this proposal had to be altered from two-thirds to one-half in 1848, but although last year a special Act was passed again, altering the two-thirds to one-half, it is believed it will not be sufficient to overcome the present state of conflicting interests, owing to the variety of tenures, and the conflicting interests between landlord and tenant.

Another defect is, that the Commissioners of Public Works have the power of determining whether the cost of the works should be repaid in 22 or 35 years, while the public consider that 22 years is much too short a time to allow for the repayment of the cost of permanent improvements.

Lastly, the Commissioners have the power of refusing to sanction the formation of sub-districts, even supposing one-half of the owners of the damaged lands are in favour, if one-third are opposed to the improvements. (See Drainage Act for 1878.)

I have reason to think that a new Act for the United Kingdom, drawn very nearly upon the same lines as the existing Acts for Ireland, omitting their defects above referred to, would confer a great benefit upon the people in the three countries. Under a new general Act, I would provide that the owners of one-tenth part of the flooded lands, having formed themselves into a committee, should be given authority to apply to the Board of Works or the Local Government Boards (whichever might be considered best by Parliament) for permission to make a preliminary survey and section of the main river in any river basin from the outfall of that basin, to whatever distance up the country the floods injuriously effected the lands adjoining.

This survey should record the dimensions and levels of the main river, as well as all artificial works in same, and the approximate ordinary flood discharges of the previous winter from each of its tributaries, as well as the approximate discharge of the main river floods a little below the junction of each tributary, and on the section should be marked the levels of the highest-known flood; on the plan should be marked the population and position of all towns and villages, and their sewage works or their outfall for same, together with two blue contour lines. Contour line No. 1 should embrace all lands covered with flood waters. Then, supposing the surface of the floods were frozen throughout the entire river valley, contour line No. 2 should embrace all the land lying 5 feet above the ice surface throughout the valley, so to speak. On the preliminary section should be marked, by the committee's engineer, the height of the proposed embankments, or the dimensions and character of the proposed excavations and other new works. The committee should then forward a petition to the Board of Works, or Local Government Board, defining the different subjects to be treated, and asking them for a report on the project.

No further expense should be incurred until the central authority above referred to received a report from their engineering department, defining the sub-districts into which it would be practicable to subdivide the river basin, according to the position of the natural falls in existing flood levels (I mean by natural falls, that the floods in a river valley may have nearly uniform gradients for long distances, but that at the end of some 20, 30, or 50 miles, a fall of several feet may be concentrated within a space of half a-mile, and the division of a subdistrict might terminate on the down stream side of that half-mile or natural fall), revising, if necessary, the proposed scale of works, while pointing out the order in which the works in the sub-districts could be carried out. Should the report state that, from an engineering point of view, the work was practicable, then the Local Government Board could make an order defining the sub-districts. This order should also define the proportion in which each of the sub-districts should contribute towards the cost of the preliminary survey, and cost of provisional order up to that time, based upon the land within contour line No. 1 on petitioner's map, at a fixed rate per acre, the money to be paid to the committee through the Local Government Board or Board of Works, should the project have been reported upon as practicable from an engineering point of view. One year should be allowed to the petitioners to ascertain whether the owners of one-quarter of the damaged land in each sub-district, as marked on the preliminary plans, would assent to the formation of a local Board to carry out their sub-division of the work, the cost to be borne by the damaged lands in proportion to the benefit derived, less whatever proportion of the total cost of the work might, by arbitration, be assessed on the towns and villages, owners of mills and fisheries, that would be benefited by the new works.

No portion of the money, however, should be raised, nor any part of the work commenced, until the schedule defining the proportion in which the different interests should contribute was finally determined, the schedule in the first instance to be prepared by the local Board, all matters of dispute as to values to be determined by arbitration.

The general Act should provide that upon all matters of dispute as to scale of assessment being finally settled, authority should be given for the Treasury to grant a loan for the works, principal and interest to be repaid in 35 years, and in exceptional cases, where works were very heavy and costly, say in 45 years.

Should the loan for the works be granted, then all preliminary expenses incurred between the completion of the committees' preliminary survey (previously paid for) and the granting of the loan, should be paid out of the first instalment of the loan.

If from any cause, however, the loan was not asked for or granted, then the sub-district Board should have to assess themselves for the expenses incurred; this latter condition would be the "main spring" of the whole scheme, as all would have a strong inducement to surmount any little local difficulties that might exist, rather than to pay for the expenses incurred by the new sub-district Board, without obtaining any benefit beyond having the plans for a future occasion.

The preliminary schedule accompanying the preliminary maps might, in the first instance, contain one quantity for the land, and one sum for the approximate increase in the actual value of the land when protected from floods or drained, as the case may be, within each sub-district; or possibly for each of the townlands or other denominations marked on the preliminary plans, so as to avoid the expense of preparing the detailed surveys and valuations, which should contain the contents of each parcel of ground, its present actual value, and probably increased value and decimal proportion in which the different interests should contribute, until after it is known whether the sub-local Boards would be in a position to adopt the report of the Local Government or other authority defined by Parliament.

Thus at a very small expense the preliminary and general design for river conservancy or drainage works could, at the outset, be submitted to one central authority, so as to ensure that the proportion and scale of the proposed new works should be uniform throughout the whole river basin, in proportion to the flood volume to be discharged by the different sub-districts, while, at the same time, enabling each sub-division of the work to be carried out by each sub-Board in proper order, and with the same uniformity as if the whole main outfall works had been let under one contract.

This method would also have the advantage of enabling each sub-district to ascertain more closely than by any other method what the approximate cost of their divisions of the work would be before commencing them.

The above is a mere outline of a proposal which, if I had time and space to develop, would, I believe, be found to get rid of some of the principal defects in the law, as it now exists, relating to river conservancy works; I know it would get rid of the great difficulties now met with in Ireland. Unless the people in flooded districts, throughout the kingdom, can be furnished with inexpensive surveys, showing how their different interests could, at a comparatively small outlay, be beneficially effected, it will, I think, be found impracticable to induce them to work harmoniously and for their own benefit. At least, this has been my experience from 1856, during which time I have been instrumental in bringing about the formation of several sub-districts, but not until I had to overcome much opposition and difficulties. It would, I think, be premature to form any definite opinion of the River Conservancy Bill that has been read a third time in the House this session, until it is seen how the Commons are likely to deal with it. I cannot help thinking, however, that should this Bill in its present form become law, it is likely to become an unpopular measure in England, on account of the power it would give to tax a dry, hilly, or mountainous district in one county for river conservancy works, or the draining of wet land in another county (purchased perhaps, a few years ago for a small sum of money); and although it is not proposed to extend the Act to Ireland, still it would prevent the owners of flooded land in that country, assenting to any new works, in the hope that a similar Act would be passed for Ireland. While the law having for generations secured the owners of dry up land in Ireland from contributing towards the drainage of wet lands, they would be forced to get up an agitation that would for years prevent any extension of river conservancy works in that country, and I am inclined to think the same objections may apply to England. If it can be shown that a River Conservancy Act, based somewhat on the above proposal, would undoubtedly confer a benefit on one part of the United Kingdom, it can do no harm to carefully consider whether the same Act might not be made applicable to the whole country.

In the event of Parliament requiring that all interests proposed to be taxed for river conservancy works should be represented in proportion to their interest, on the Boards having the powers to tax them, I much fear that as over 90 per cent. of the land in each river basin would be above the influence of river floods, that the owners of that land would be powerful enough to successfully resist or defeat any proposal to tax their lands for river works, required to relieve from the injurious effects of floods or pollution the remaining 10 per cent. (in many cases not so much) of the river basin, and possibly belonging to another set of proprietors, while the scheme I propose would avoid this latter danger.

RIVER CONSERVANCY, ILLUSTRATED BY DRAINAGE ADMINISTRATION IN HOLLAND.

By J. Clarke Hawkshaw, Memb. Inst. C.E.

The word "Conservancy," when applied to rivers in this country, has generally hitherto been held to mean the keeping of them in a fit state for navigation. When our rivers were more used as highways, most of them had Conservancy Boards for navigation purposes. As long as such bodies prospered, our rivers were kept in far better order than they now are, not only for navigation but for other purposes. Some of these Boards have disappeared, some remain, and still retain their powers, but many are unable, for want of funds, properly to do their duties.

For this reason, and from the growth and spread of population along the river banks, new forms of conservancy have become necessary. Pollution by town refuse led to the passing of the Rivers Pollution Prevention Act, in 1876. The greater frequency of floods during late years has made it plain that conservancy for their prevention is necessary, and has given rise to the Rivers Conservancy Bill of this Session in Parliament.

Land Drainage Boards we have in plenty; each one does something, often little enough, to ward off floods, in its own district. But their sphere is too limited, they rarely look beyond their own narrow banks, and they will not work together. What we want to find out is how to control and direct their work, so that, when possible, it may be made to benefit all, and also to aid it by works which no one of them could undertake.

Some advance has already been made towards the same end in other countries, and we may help ourselves in our difficulty by seeing how it has been met elsewhere.

Of all neighbouring countries, Holland has the most artificial system of drainage. The very existence of the country depends on the water in and about it being kept under proper control by artificial means, and this has been the case from very early times. We might therefore reasonably suppose that the necessity for laws to control and provide for the management of rivers and water channels would soon have been felt in Holland and such we find to have been the case.

Unions for drainage purposes of all lands, high and low, have existed in Holland for several centuries. Such unions are called "Waterschappen," and their oldest charters date from the 13th and 14th centuries.

In early times, the Boards of the Waterschappen were composed of the already existing corporations, and the Government of the day named persons called "Heemraden" to control and superintend the land drainage works which the corporations carried out.

Under these corporations no great progress was made until the 15th century. As the importance of the works which were undertaken increased at that time, so also the necessity then arose for a more complete organisation, to supervise and control them, and more important administrative unions, called "Hoogheemraadschappen" were accordingly instituted on a basis which has remained practically unchanged to the present day. A Hoogheemraadschap is a Waterschap, whose Board is composed of a "Dykgraaf," or president, and "Heemraden," or directors, with power to execute and maintain all the drainage works in which the inhabitants of their district have a common interest, with power to control all the minor works carried out by the small drainage corporations or "Polders" and to enforce obedience on the part of private landowners and Polders to such laws as they may from time to time make.

The following powers are possessed by all the Waterschappen:—

1. In cases of emergency, when floods are imminent, they may execute works, or remove existing works, at the expense of those who should execute or remove them, but who fail to do so.

2. They may appropriate any materials which may be of use in repelling floods. The compensation to the owners to be settled afterwards.

3. They may take the earth required to make new or restore old embankments. The compensation to the owners to be settled afterwards.

4. They may levy rates to defray their expenses.

They may, moreover, by a law of 12th July, 1855, inflict a fine, not to exceed 25 florins, or imprisonment for from one to three days, for infringment of their regulations. The intervention of a judge is required, however, to legalise these punishments. They may also shut up or put out of use all the watermills, sluices, or other works by which interference with their regulations has been brought about, and this may be done at the expense of the offending owners. The Hoogheemraadschap of Rhineland is one of the most important of the large drainage districts in Holland, and I will describe its constitution in somewhat more detail, from information kindly furnished by its president, Mr. J. S. Clercq, and by Mr. J. Waldorp, the eminent Dutch engineer.

Its first charters were granted by William II., Count of Holland, in 1255, and by Count Floris V., in 1285. It extends from Amsterdam to Gouda, over an area of 262,685 acres (106,282 hectares). It is bounded on the north by the margin of the recently reclaimed Lake Y, on the west by the North Sea, and on the south and east by the Hoogheemraadschaps of Delfland and Amstelland. There is an adjoining district of Woerden, 41,992 acres (16,990 hectares) in extent, which pays a fixed contribution for certain sluicing privileges, but which forms by itself a separate Waterschap.

The administration of Rhineland consists of a combined board, composed of 16 chief or principal landowners, six members, called Hoogheemraden, and a president, called Dykgraaf. The Dykgraaf and six Hoogheemraaden form an executive board, over which the Dykgraaf also presides, and which is assisted by a secretary, a receiver, and a civil engineer.

Besides the 16 chief landowners, there are 16 chief landowners assistant. The two together form an electoral body of 32 in number, which meets once a year, to select three persons, either for Hoogheemraden or Dykgraaf. This list is submitted to the king who chooses one of those named in it to fill the office.

No one under 23 years of age can be a member of the Board, or a member of the electoral body, and in order to be elegible for the office of Dykgraaf or Hoogheemrad, a person must be the owner of at least 62 acres (25 hectares) of land in Rhineland, and chief landowners, and chief landowners assistant must own at least 50 acres (20 hectares). Relations nearer than the second degree cannot serve together.

Rhineland is divided into 16 electoral districts, each of which elects one chief landowner and one chief landowner assistant. All persons, companies, and corporations paying yearly taxes for not less than 2½ (1 hectare) have a right to vote. The payment of taxes on 2½ to 12½ acres (1 to 5 hectares) gives the right to one vote, and so on up to 200 acres (80 hectares) which gives the right to the maximum number of votes, which is ten. The vote may be given by written procuration.

All the members of the combined Board, including the Dykgraaf, and also the chief landowners assistant who serve only on the electoral Board, are elected for six years, and a certain number retire each year.

The combined Board has charge of everything connected with the constitution of the district; it decides on the regulations to be enforced, and on the measures to be taken to enforce them; it decides on the execution and manner of carrying out all new and extraordinary works; it determines the right to pump or sluice on to the general bosom or upper catchwater; it buys, sells, and leases the property of the Hoogheemraadshap; it decides when action shall be taken in the courts against those who fail to comply with its regulations; lastly, it settles all disputes between the landowners or minor polder Boards. Against its decisions in such cases appeal may be made to the Deputy States of the province; in the case of Rhineland, to the Deputy States of North and South Holland.

The executive Board, consisting of the Dykgraaf and Hoogheemraden has charge of the execution of the resolutions of the combined Board. In cases of emergency, it may act independently, and at such times it may carry out any works it thinks necessary, may make banks, occupy land, and take any materials it may require from adjoining occupiers.

The executive Board may order the removal of any obstructions which interfere with the drainage of the district, or it may remove the same at the cost of the owners if they fail to do so; it regulates all deep excavations, whether for peat or other purposes; it sees that proper precautions are taken to prevent the sand of the sandhills from blowing away; it fixes the level at which the water has to be maintained in the different catchwaters or bosoms; it controls, in fact, all works affecting the drainage of the district.

The Executive Board publishes the regulations, and sees that they are enforced, and it keeps a correct register of all the taxable lands of the district.

The Dykgraaf is charged with the execution of all the resolutions of the Executive Board, and he has control over all the officials of the Hoogheemraadschap. In cases of immediate danger, he may act independently, with the full power of the Board.

The regulations prepared by the executive Board, after being open for public inspection, for 14 days, are submitted to the combined Board, who send, them with or without modification, to the Deputy States for approval. After being approved by the Deputy States, they are published, and eight days afterwards are in force.

The yearly budget, which includes the salary of the Board and its officers, the expenses of the Board, the cost of maintainance of all ordinary and extraordinary works, and all other expenses, is prepared by the Executive Board, is settled by a general meeting, and has then to be approved by the Deputy States of the province. At the same time, the tax to be paid by the landowners is settled for the following year. The tax is fixed at an equal rate per hectare (with a few exceptions, resulting from old contracts, or for reasons, which will be referred to later on) and is the same, whether the lands are high lands, or low lands. Uncultivated sandhills, and the water area of the bosom, and bosom canals are free from taxes. The average yearly tax paid during the last 50 years in Rhineland, has been one shilling and four-pence per acre (two florins per hectare); the maximum tax in any year was two shillings, and the minimum eight-pence per acre (three florins, and one florin per hectare).

The Budget, after being open for public inspection for 14 days, is printed and published, and the same course is pursued with regard to the amount of receipts and expenses for the past year.

All payments are made by the Receiver (Rentmeester) and the certificates are signed by the president and one member of the Executive Board. All other documents are signed by the president and secretary.

The taxes are paid in accordance with the register, which contains a correct description of all the properties in the district. This register is open for public inspection, during a fixed period.

If Rhineland neglects to execute necessary works, the Deputy States may order the execution of them, or may undertake them themselves, and charge the cost to Rhineland the Deputy States may also propose to the King the dismissal of the Dykgraaf or Hoogheemrads, when they are either inefficient, or when they fail to carry out the requirements of the Deputy States. In all cases the King decides between the two. Any information which the Executive Board may require from the Polders Corporations in Rhineland, must be supplied by them, and they must submit to the Board their yearly budget, and an account of their administration. They may, however, appeal to the Deputy States against the Board's decisions.

In the years 1854-5, the Provincial States of North and South Holland settled general rules for the administration of the Polders Corporations, 230 in number, over which the Rhineland Board has general control. Each Polder has its own special rules.

Any resolution of the Hoogheemraadschap, or of the small administrations of Rhineland, may be annulled by the deputy states, if it is contrary to law, or if it is against the interest of Rhineland, or that of the province. The only appeal in such an event is to the King.

Such is the administration of the important district of Rhineland. Other districts throughout the country are governed in a similar manner.

It is generally thought in Holland, that the existing laws are all that is required to secure the good administration of the Waterschappen, and smaller drainage districts, or Polders, which they include. In confirmation of this opinion, I am told that disputes between the different interests in the large districts do not often happen, and the right of appeal to the Deputy States against the decisions of the different Boards is very seldom used. It is, however, thought that a law is required to regulate the relations of the large districts to one another, to the towns, and to the navigations. Yet, although the want of such a law has long been widely felt, the landed interest in the chambers, who are most interested in obtaining it, and who are, moreover, in a position to do so, have not yet ventured to move for it. The administration of the Waterschappen and Polders is so good, and all interests within them are now so well protected, that there is great reluctance to take any steps which may tend to disturb or lessen the authority of the existing Boards.

In a flat country like Holland, well-defined natural drainage districts do not exist. When drainage districts are not divided by natural boundaries, the interests of those which adjoin must often be opposed, owing to their making use of common channels for the discharge of land water, or from other causes; and hence arises the necessity for a law to regulate their mutual relations. In this country, no such necessity need arise, if the boundaries of the combined drainage districts are made to coincide with the natural boundaries of the river basins, which are well defined, except in limited areas, such as are met with in the few districts of the Eastern Counties, where flat, alluvial tracts stretch across the lower courses of two or more rivers.

The whole of each natural drainage district should be under one Conservancy Board; above all, it is important that the outlet, by which the waters of the district are discharged into the sea, should be under the same control as the rest of the district. On many rivers, it will be found that the cost of the works inland will depend, to a great extent, on what can be done to improve the outlets to the sea, and, if these outlets are not, in some measure, under the control of the Conservancy Board for the river, their difficulties and expenditure may be very much increased.

If Conservancy Boards are formed for drainage purposes with only partial jurisdiction over a river, they will always be able to drain their land, though, perhaps, at greater cost, without the cooperation of those situated lower down on the course of the river. But those so placed lower down will not save their pockets by not forming part of the same conservancy district, for unless they make provision for the more rapid discharge and greater volume of flood water, which will result from the works carried out above, they must suffer, more or less. This has happened in many places already, when works have been carried out by landowners on river banks without the co-operation of, and without regard to the interests of those lower down; and the same thing may happen if the drainage area near the river mouth is not under the same control as the rest of the river basin. Many of our ports are liable to be inundated by high tides, landwater floods, and combinations of the two. If the flood waters are passed to the sea more rapidly by improvements, this liability may be increased. It is therefore most desirable that no part of each natural drainage area should be left out of the union for conservancy purposes, least of all the lower parts adjoining the sea. If all are included, the interests of all can be watched and considered, and the best results may be obtained at the least cost.

In Rhineland, all lands, high and low, are obliged to contribute, in proportion to their acreage, to the general rate raised for the purposes of the Waterschap. Generally, the amouut of the rate is the same, per hectare, for all. Exceptions are occasionally made in favour of some lands—when it can be proved that no benefit whatever can be derived by them from the works for which the rate is raised. In such cases the tax is not wholly remitted; the lands are taxed at a lower rate. The principle that all lands, high and low, should contribute, is, I think, fair and right, but it may appear unjust that the rate should ever be of the same amount for the two descriptions of land. It must, however, be borne in mind that in Holland lowlands bear a very much larger proportion to the total land than in this country.

For example, the total area which drains into the general bosom of Rhineland is 302,600 acres (122,450 hectares). Of this, 26,740 acres (10,821 hectares) only, that is, less than one-eleventh of the whole, consists of high land. This lies wholly within the district of the sandhills along the coast.

Of the remaining area 35,689 acres (14,442 hectares) are bosom lands. These are also held to be highlands in Holland, but they would not be called so in this country, as their average level is ten inches, (·25 metres) below the mean level of the sea. The polders or lowlands in Rhine-land lying from 3¼ to 5 feet (1 to 4 metres) below mean sea level, are 231,170 acres (93,546 hectares) in extent, and, lastly, the area of the bosom canals and lakes is about 9,000 acres (3641 hectares).

The bosom lands serve a special purpose in Holland. The water is pumped from the polders or low-lands into the bosom canals which run through the bosom lands, and it passes by them through sluices to the rivers or the sea. The bosom lands are liable to be flooded at times, indeed they form an additional reservoir space to supplement that afforded by the bosom canals and lakes. The bosom lands, together with the bosom canals and lakes, form the general bosom of a district. Flooding of any part of the polders is of the rarest occurrence. The pumps on which they are dependent are never stopped until the water rises to such a height on the bosom lands as to endanger the banks which divide them from the polders. If the banks were to give way, all the water stored on the bosom lands would inundate the polders. Rather than risk such a serious flood, the pumps would be stopped, and the rainfall would be allowed to accumulate on the lowlands for a time.

In the Fen districts of this country much of the land corresponding to the bosom land of Holland has been separated from the general bosom, and the receptacle for flood water has been thereby diminished. Such mis-appropriations are still going on, and, though a few landowners gain for a time by them, they, as well as their low-lying neighbours, must suffer in the end. The so-called dales along the River Witham were bosom lands; they now form part of the Fens, though the old banks which separated the two in former times still remain in places. In Holland, no such conversion of the bosom land into polder land would have been permitted. That the area now left for bosom water is wholly insufficient in the Witham district, was shown by the disastrous floods which happened in 1877. In this country there is no Board, as in Holland, with power to say when it is no longer safe to pump water from the fens on to the bosom. Each fen continues to pump, quite regardless of the height of the bosom water, which may often be running back over the banks to its own pumps. The banks must give way sooner or later, but each fen hopes that its own bank may not be the first to fail. The failure of a bank may cause one or more fens to be submerged to a depth of five or six feet, whereas a few hours' cessation of the pumping throughout the district, might often prevent such a disaster. In Rhineland, by stopping the pumps which drain the polders, a serious flood may always be prevented, but it would not always be so in this country, for we have to contend with an immense volume of highland water, which is not the case in Rhineland.

It is now an accepted fact that the water from much of the highlands is discharged more rapidly into the rivers than it used to be. An owner of high land may say, "I bought my land subject to no charge for a river conservancy" rate; but with equal truth the owner of lowland may reply, that when he bought his land it was not liable to be overflowed by the large volume of water which the owners of the high lands now pour into the river by their improved system of drainage. But apart from such arguments, which are only of partial application, the principle that all lands should pay to maintain the main channels which, directly or indirectly, drain them is surely a fair one. If the incidence of rates is only to be determined by the benefits received, very many could not be justified.

No doubt the lowlands will benefit most, as now they suffer most, and they should bear the largest burden of the cost: the more so as they have to some extent rendered themselves more liable to be flooded, and have in many cases made the works which will be required to prevent floods more difficult to design, and more costly to execute.

In the first instance, costly works will often be required; works designed only to meet local requirements will have to be done over again, or be done away with altogether; obstructions will have to be removed which have grown up in the river channels, from natural causes, during years of neglect, or which may have been placed there to benefit individuals.

But even for such works no such rate need be feared as the land in Holland is subject to. Holland has to provide an artificial drainage for nearly all the land; we have, in most cases, only to provide that a good natural drainage system is kept in order, for, fortunately, the land in this country, which is without a good natural drainage, is very small in extent, when compared with the whole area.

To make a satisfactory law which shall provide for the government by one body of such large districts as are drained by our rivers, is a task of extreme difficulty. To put it in practice will be more difficult. The interests which have to be dealt with are so many and so great that it will be impossible to satisfy all. In Holland, where want of such a general law is more keenly felt than here, they have not ventured yet to prepare it. Still, they are far before us in river conservancy. They have large districts admirably administered, and under the charge of able drainage engineers, and they, moreover, have recognised the principle that all land should contribute to maintain the channels which convey the water flowing from it into the sea.

THE SANITARY STATE OF THE VALLEY OF THE RIVER SHANNON REFERRED TO BAD REGULATING WEIRS.

By **James Lynam, C.E.**, of Ballinasloe.

To regulate the flow of rivers so as to restrict them from doing evil, and to lead them to do good; to prevent injurious inundations, and provide for fertilising irrigation; to maintain useful lines of navigation; supply good water to towns; and to drain malarious marshes, and make them healthful, profitable lands, would be to confer immense benefits on these kingdoms. To accomplish all this is quite practicable. It has been done to a great extent in Ireland under the drainage laws, with money borrowed from the Government on easy terms. Every one of those many loans has been, or is being, most regularly paid back, with interest, by the landowners who expended it.

The regulating of the English rivers is about to be commenced on a very large scale, under the law now being promoted by the Lord President. To bring rivers under the control of man, different regulating weirs are essential. I have reason to know that they may be designed and constructed of simple machinery, so as to very materially lessen the amount of excavation, which even the most eminent engineers have hitherto calculated on as necessary. Many patterns of regulating weirs in rivers are to be seen; some very effective, many very bad. Three patterns have been for many years in action in the River Seine. They are very effective, and fulfil the important object of regulating that great river, with an immensely valuable navigation from Elbœuf to Paris, and many miles upwards. Another pattern more suitable to the English and Irish rivers, and more agreeable to our notions of permanent security, has been designed. The regulating weirs in the Shannon river in Ireland are on the same principles and style as those in the Severn. Solid masses of stone work, extending obliquely down stream, partly like a half parabola, without any sluice or flood-gate, or falling-board. In the Severn they are a success, in the Shannon they are an utter failure. The reason is, that the two rivers differ widely in circumstances and *régime*. The Severn has had but one summer flood in 40 years; it has frequent winter floods from the Welsh mountains, which rise rapidly, and cover the weirs several feet deep. The surface of the river just below the weir rises so high as to be very nearly level with the surface just above. Then "the whole trade goes over the top of the weir, where the river surface is practically level." The late Mr. Williams, the Severn engineer, stated he has seen "a whole train of vessels, half a mile long, behind a steam-tug, all taken over the weir, without knowing where it was."

The Marquess of Ripon asked—Have weirs on this principle been built anywhere else than in the Severn? Mr. Williams answered—No. The adoption of this principle was the result of six weeks' discussion we had in Parliament in 1842. The Marquess of Ripon—As it has been in operation there for 35 years, is it not curious that it has not been adopted elsewhere?

The Shannon Commissioners, composed of five eminent engineers, adopted that principle, and built six such weirs across the Shannon. They are great, broad solid masses of stone, in plan resembling a half horseshoe, extending down stream obliquely for 1,100 feet length, where the river just above is but 400 feet wide, as at Killaloe and Meelick. But though these weirs have improved both drainage and navigation in the Severn materially, as described by Mr. Williams, in his evidence reported by the Select Committee of the House of

Lords in 1878 (see evidence, pages 162, &c.), they have not at all improved the drainage of the Shannon, whose circumstances differ widely from those of the Severn.

The Shannon, for 111 miles above Killaloe, flows through a broad flat valley, with a fall of but 36¾ feet, apparently 4 inches per mile. But of that length 50¾ miles consist of broad deep lakes, having an area of 75.000 acres, capable of storing 6,000 million cubic feet of surplus flood-water. Broad, deep channels of the river between the lakes, of the aggregate length of 55 miles, are so capacious as to carry the flood-waters with a fall of merely 1 inch per mile. For 4 miles the channel is confined, causing a little obstruction to the floods. But the parts of the channel that are material obstructions, visible to the eye, are but two, about a mile long in all. From these circumstances it would appear that the Shannon may be very easily regulated, and its valley drained; and so it may, if proper regulating weirs were adopted. The present solid, wholly immovable weirs are the great obstructions in the Shannon. In dry summer weather they serve the navigation, and do no harm to the low lands, which are from two feet to five feet over the legal level of the navigation. In wet weather, which often happens in spring, summer, and autumn, they do very great harm to the land. As the surplus water increases from the rainfall, and finds no corresponding increased outlet at the weirs, it rises with every successive rainfall more than it can fall in the intervals, until it fills the river and lakes to the level of the low lands, or an inch or two under or over these lands. These conditions exist many years, during long periods in spring, summer, and autumn, not continuously, but at frequent intervals. In such intervals of small floods, there is not time for the low lands to become dry. It often occurs that the river is low in March and April, and many small farmers plant their potatoes, and sow their oat crops, and afterwards the river rises early in May, fills the drains and trenches, saturates the soil, and rots the seed. Such almost continuous saturation of the soil of the Shannon Valley, 150 miles long, and laterally along 17 tributary rivers, whose outlets are obstructed by the Shannon, is a very great public evil, so very injurious to the industry, the wealth, and to the health and vigour of the inhabitants. The atmosphere is much damper, and the temperature much colder than it should be. The land is, of course, far less valuable. Kind, nutritive species of the grasses cannot grow; coarse sedges, and soft aquatic plants occupy the soil. All attempts at farm drainage and improvement are impossible. In autumn frequent floods occur, of so small a magnitude, as could easily pass off by ordinary sluices; but there are none, and those floods go over the fields to a depth of merely a few inches for a few days. But they foul the herbage, and make it very unwholesome for cattle, quite unfit for sheep. The losses among the cattle and sheep by these causes are every year material, but this year may be reckoned by thousands of pounds. I have seen the crops on both sides of the Shannon for many miles rotting under merely a few inches of flood water, while at the weirs below, there was a clear fall of some feet, a cataract over each weir-wall. On one occasion I noted the falls over the weirs, when the valley was flooded by only from one foot to two feet of water. At that time the whole fall of the river, from the town of Carrick-on-Shannon to Killaloe was 36¾ feet. Of that fall, 21 feet were wasted in cataracts over six weirs, while 15¾ feet merely were spread along the surface propelling the stream.

The great winter floods make a continuous sheet of water 150 miles long, running laterally into many bays and tributary rivers, covering many public roads, surrounding and isolating many lots of high lands, and entering many dwelling houses. In one locality, I inspected 13 dwelling-houses so flooded. The people had constructed platforms of sods and stone under and around the fire-places. They showed me the stones and chairs on which they stepped to their beds, where they slept with several inches depth of Shannon flood water on the floor under their beds. The flood had then subsided 4½ inches from its highest, as I noted by the marks it had left on the legs of the beds and tables. Many other families had abandoned their homes, and gone to the neighbouring towns till the floods subsided, when they returned to live and sleep in such apartments, with much danger to their health.

During all such times of misery, the weir mounds stand up firmly across the whole river, permanent artificial obstructions to the flood waters, robbing the river of half of its natural fall.

I cannot give the statistics of disease and death, in the saturated valley of the Shannon. I leave it to the humane minds of our philanthropists to imagine it, and to estimate how far this deplorable condition of a large and interesting district of her Most Gracious Majesty's kingdoms, is or is not due to her Majesty's Government. These most unscientific and unsuitable weirs were designed, recommended, and built by Government Commissioners. They have been maintained and defended, with all their evil effects, during 35 years, by Government Commissioners, who have bluntly refused several applications from proprietors for liberty to construct sluices in them.

To the great fault in the design of those wholly immovable weirs, those Commissioners added another great evil, when constructing one of them, viz., that at Killaloe. They built it a foot higher than is warranted by the Parliamentary section drawn by themselves, and recommended to Parliament, on diagram No. 39 in their second report. They neither asked for, nor got any authority for that direct violation of the Shannon Improvement Act. The Commissioners still rigidly maintain that violation of the Act of Parliament, and without any necessity. The navigation channel all the way is deep enough for the steam boats without it. They refused a formal application from the landowners for liberty to put sluices in it. The evils of that illegal and unnecessary foot of height of the Killaloe weir extends up the Shannon 31 miles, and laterally along eight tributary rivers. I have seen the hay crop rotting, and the herbage on the pastures all spoiled by saturation of small floods, merely three to six inches deep, while that illegal, and quite unnecessary extra foot height of the Killaloe weir was protected and persistently preserved by the Government Commissioners.

In response to an invitation to write a paper for your meeting, I offer this, in the hope that it may be useful to sanitary and to river engineering interests. I pledge my word for the truth of every part of this statement.

In the name of the many sufferers by the evil effects of the Shannon weirs, I earnestly implore the Society of Arts to give some attention to the very unwholesome state of the valley of the River Shannon, and to use their great influence with the Government to induce them to abate the great public nuisances they have placed there. This may be easily done in one year, by constructing six movable regulating weirs of iron and wood, in lieu of the present six wholly immovable, unscientific, and unsuitable stone weir-mounds. By their means all saturation in the valley would be directly terminated for ever, and also all flooding of roads and houses; none but great winter floods would go over the lands, and those would not rise high nor last long, and would do some good as irrigation on the meadows. No great amount of excavation is necessary to give them full effect.

ON THE WATER SUPPLY OF THE UPPER BANN RIVER, IRELAND, AND THE AMOUNT OF RAINFALL UTILISED.

By John Smyth, Jun., A.M., C.E., F.C.S., F.M.S.

It is proposed in this paper to describe shortly what has been done to conserve the surplus water supply of the valley of the Upper Bann River, the success which has attended the work, and the amount of the rainfall made available.

The River Bann rises in the Mourne Mountains, and flows in a northerly direction, passing through Lough Neagh, where it receives many tributaries, until it falls into the North Atlantic Ocean at Coleraine. Its course is 85 miles long, and its total drainage area, including the surface of Lough Neagh, is 2,345 square miles. It is thus the third largest river in Ireland, being surpassed only by the Shannon, and the Barrow Nore and Suir. The most of its branches arise at a high elevation, and have a rapid descent towards Lough Neagh, thus affording along their banks favourable sites for mills. This circumstance has been well taken advantage of by the industrious inhabitants of the district, and contributed largely, I believe, to the establishment of the linen trade in the North of Ireland. The Upper Bann, of all the branches or tributaries of the Bann or Lough Neagh drainage system, is the most interesting, as an example of the highly successful application of engineering science to the development of its natural resources. Mills existed on it at a very early date. It is said that, in 1772, there were 26 bleach mills upon the Upper Bann, and that the linens bleached therein were well known and much esteemed in England and Scotland. Previous to the year 1833, the water power of the river was made available for mill purposes, by means of wooden undershot wheels, but in that year the late Sir William Fairbairn erected the first iron breast wheel at Hazelbank mills, and thus nearly doubled the power previously obtained from the water. Other mills soon adopted the more efficient wheel, and business having increased, machinery was extended. The advantages thus gained from the waterpower was so great, that the desirability of extending those advantages to every season was soon seen. In the year 1835, therefore, the Bann Reservoir Company was formed, to provide a better and more regular supply of water to the mills. They placed the matter in the hands of the late Sir William Fairbairn, F.R.S., who, assisted by Mr. J. F. Bateman, F.R.S., surveyed the rainfall collecting grounds of the river, and made an excellent and most interesting report of the water-bearing resources of the district. He recommended the construction of two impounding reservoirs, Lough Island Reavy and Deer's Meadow, and one auxiliary, reservoir Corbet Lough. Lough Island Reavy reservoir was first constructed according to the plans and under the superintendence of Mr. Bateman, and was finished in the latter part of the year 1839. The Corbet reservoir was also constructed, but not to the full extent contemplated, the embankments having been made to impound only 11 feet 3 inches, instead of 18 feet depth of water. Much difficulty was encountered in the work, which was not finished till the year 1847. The Deer's Meadow was abandoned, as the works were of a heavy character; and, the gathering ground being small, it was feared there would not be enough of water to fill it. Lough Island Reavy reservoir is situated in a narrow valley on the north-east flank of the Mourne Mountains, and receives three-fourths of its supply through a conduit from the Muddock river, a tributary of the Bann, and one-fourth in the same manner from the Moneyscalp river, which does not belong to the Bann drainage area, but flows into the Irish Sea near Newcastle, about six miles from the reservoir. The water is impounded to a depth of 35 feet above the old lake, which existed there, and at top water is 430 feet above sea level. It can be drawn off to a depth of 38 feet 6 inches below top water. The area of the reservoir, when full, is 250 acres, and the capacity 270 million cubic feet. The water is discharged from the reservoir through two 18-inch iron pipes, secured in a culvert built in the solid ground beneath the main embankment, and is conducted by an open channel to a point a mile down stream, below the in-take, where the supply is lifted. After flowing down the Muddock river for six miles, the water reaches the Bann. In the first three miles down the Muddock, the descent is rapid; in the last three, however, the stream is sluggish and very sinuous, and the banks are subject, after heavy rain, to be overflowed, not only by the floods of the Muddock, but also by those of the Bann. This result is rendered more certain by obstructions in the Bann at the mouth of the Muddock river.

These floodings, and also minor ones, caused by the overflow of some of the lands when the water is being sent down to supply the Bann, owing to obstruction from weeds and the silting up of the channel, have been the source of actions being taken against the company. This difficulty arose from a dispute as to whether the reservoir company or the riparian proprietors should cleanse the stream. The company contended that as the river was a natural watercourse, over whose banks they had no power, and on which they could not throw out the cleansings without permission from the proprietors, they were not bound to clean out the river. The riparian proprietors, on the other hand, contended that the company had altered the flow of the stream, by impounding the water at one season and sending it down at another, that thus the stream was an artificial one, and the company were bound to keep the channel clear, so that no injury should accrue to them.

When the case was first brought before the Judge of Assize, the jury gave a verdict in favour of the company; this verdict was, however, set aside by the Court of Queen's Bench, and a new trial was granted. At the new trial the case went against the company, and on appeal to the Queen's Bench, the same was confirmed. The company then appealed to the twelve Judges in Exchequer Chamber, the majority of whom gave the case in their favour. The riparian proprietors then appealed to the House of Lords, where the case was finally determined against the company. The reservoir company, therefore, made an arrangement with the proprietors for the removal of the cleansings, and cleaned out the Muddock river last summer. The proper supply for the mills can now be sent down to the Bann without overflowing the channel, and the directors have erected a gauge weir board across the channel, at a short distance below the discharge-pipes, the better to regulate the supply sent down. From the mouth of the Muddock river to Ervin's weir, where the surplus water is lifted and taken into the Corbet reservoir, a distance of eight and a half miles, there is about 30 feet of unoccupied, and 7¼ feet of occupied, fall on the River Bann. At this weir, the caretaker daily measures the quantity of water coming down the river, and thereby regulates the amount to be supplemented by the reservoirs. The channel of the feeder from this weir to the Corbet reservoir is about a mile long, and wide enough to take in considerable floods. The area of the Corbet reservoir is about 70 acres when the water is at top level, or 11¼ feet, above the discharge outlet. The water is discharged through an iron sluice three feet wide, and capable of being raised one foot high; there are two other unused sluices of the same dimensions. The cost of these works has been about £30,000, the income is derived from a rate of £10 per annum per foot of fall, levied on linen bleachers, manufacturers, and spinners, and £5 on corn and flax-scutch millers. The fall from the outlet of Lough Island Reavy to the tail water of the last mill is 350 feet, of which, however, at present only 180 feet can be rated. The dividend has not averaged more than three per cent.; if, however, litigation ceased, and all the falls were occupied, it would pay very well. Lough Island Reavy reservoir has now been at work for nearly 40 years, and has well borne out Sir William Fairbairn's anticipations of its utility in supplying water. In his calculations he assumed the yearly rainfall at Lough Island Reavy as 36 inches, since no extended rainfall observations had then been made, and at that time 36 inches was considered the average for all Ireland. He allowed one-sixth for absorption and evaporation, and concluded there would be sufficient to fill the reservoir one and a quarter times, on the average, in the year. As I was much interested in the question of the rainfall, and the amount available for water supply, I commenced, eighteen years ago, to keep a rain gauge at Banbridge, which is about 20 miles by the course of the river below Lough Island Reavy. At the same time, too, I had one erected at Lough Island Reavy, where the caretaker took the daily observations, and forwarded them to me weekly. In the year 1874, I read a paper at the Belfast Meeting of the British Association, on the Rainfall of Ulster, for which Mr. G. J. Symons, F.R.S., furnished me with the most important statistics. In the discussion on the paper, regret was expressed that there were so few rain-gauges in Ireland, and it was resolved that observers should be invited, and gauges furnished, as far as the grant from the Association would warrant, to those who asked for them. Mr. Symons, therefore, as Secretary of the Rainfall Committee, published a letter in the Irish papers, in accordance with the resolution. I am glad to say that a large number applied—greater, indeed, than the grant could afford gauges to, and amongst them, several from the Bann Drainage District and neighbourhood, for whom, by providing a few gauges myself, I ensured a supply. Besides the two already at Banbridge and Lough Island Reavy respectively, there is one at the intake to the Corbet reservoir, kept by the caretaker; one at Kate's-bridge, two miles further up the river; one at Hilltown, about two miles up the river, above the mouth of the Muddock river; and, for the years 1875, 1876, and 1877, I employed the highest inhabitant on the Butter-mountain to keep one for me, at an elevation of 930 feet above the sea, and about three miles further up the course of the Muddock river than the intake to Lough Island Reavy reservoir. All these observers are inside the drainage area of the upper Bann river. The average rainfall for the last seventeen years at Banbridge is 31 inches; at Lough Island Reavy, 45 inches; and, for the three years mentioned above, at the Butter mountain, 83·1 inches. Since I wished to have a register of rainfall at a still higher elevation, and Mr. Crawford (one of the Directors of the Bann Reservoir Company) was anxious to know the rainfall at the Deer's Meadow mountain, the site of the reservoir not yet carried out, we jointly engaged an observer there, and removed the mountain guage from the Butter mountain to the Deer's Meadow mountain, to a point 1,050 feet above the sea level. This station was about two miles from any house, and the caretaker visited it weekly, but after three months it was interfered with, so it had to be taken up. I am in hopes soon of being able to get a man to keep the gauge at a high elevation on the other, or south side, of the Deer's Meadow mountain. Basing our calculations on the foregoing available rainfall statistics, as the rainfall at the level of Lough Island Reavy is 45 inches, and at an elevation of 930 feet, 83 inches, it must be still more for all elevations between 930 and 1,600 feet (the highest point of the mountain). The ridge of the opposite side of the drainage area, however, is not so high, so we may assume 60 inches as the average rainfall, which is something less than the mean between the minimum elevation at the reservoir, and the maximum at the elevation of 930 feet. The drainage area of Lough Island Reavy is five square miles, and the year's rainfall would, therefore, be 697 million cubic feet. The capacity of the reservoir, filled to 38 feet 6 inches above the outlet, is 270 millions cubic feet; or, if there be no loss from evaporation and absorption, there would be more than enough to fill it twice over. I find it requires a fall of 30 inches registered at the reservoir, equal to 40 inches by calculation as above, over the whole area to fill the reservoir, from the beginning of October until the beginning of April (the season it is generally filled). As 23 inches fills the reservoir, there results a loss of two-fifths for absorption and evaporation; but as the evaporation from the surface of the reservoir is considerable, and there may be a loss at the intake from some water getting over the weir, when there is a large flood, it is more than probable two-thirds might be taken into the lake. It was, therefore, fortunate, Sir Wm. Fairbairn was so low in his estimate of the rainfall, as it is now evident he allowed too little for waste.

At the intake to the Corbet reservoir, where the drainage from 80 square miles of partly flat and partly mountainous country passes down the river, on comparing the amounts passed over Ervin's weir there, with the average yearly rainfall, I roughly calculate the former to be two-thirds of the latter, showing a loss of one-third for evaporation and absorption. In this calculation 30 per cent. is deducted from the results of the weir gaugings, calculated by the usual formula, for the roughness and uneven crest of the weir. I arrive at the value of this deduction from knowing the amount discharged from Lough Island Reavy, when the normal amount is passing over Ervin's weir, and making the same allowance for the gaugings. The amount taken into Lough Island Reavy over that discharged, and the amounts taken into the Corbet reservoir are, of course, allowed for in the above calculation. It is very much to be desired that Ervin's weir was levelled, and made of such a form, that more exact calculations could be made from the daily gaugings there.

The registries, now kept 32 years, show how useful the reservoirs have been. Lough Island Reavy has granted an average supplementary supply of one-half of the summer standard discharge for 3,123 days, or a yearly average of 100·9 days of 24 hours, and has been empty only 351 days, or an average of 11 days yearly.

The Corbet Reservoir Register has not been kept so long or as accurately as that of Lough Island Reavy. From the average, however, of three years, it has been kept compared with Lough Island Reavy, I calculate it has supplied one-half the amount, for although its capacity is so small, yet as it commands the surplus water of 80 square miles of drainage, it is filled several times in the year. Add this to the Lough Island Reavy supply, and there is a total of 150 days supply. Sir William Fairbairn calculated, that when all the reservoirs should be made (including the Deer's Meadow, and the full completion of the Corbet) there would be a supply of 60 cubic feet per second for 108 days of 24 hours each year. As about 27 cubic feet per second has been allowed for 150 days, if we reduce it to 108 days, it amounts to 37·5 cubic feet, which is very nearly in the same proportion to the amount that can be impounded as his calculation was to that proposed to be impounded. Since the supply has only failed on an average 11 days yearly, the standard water-power may be said to have been almost constantly maintained.

From calculations made of the amount of water flowing down the river at Ervin's Weir, I find there is an average of about 5½ billions cubic feet in the year, and the normal flow kept up by the reservoirs would amount, in the whole, to about two billions cubic feet; so, as one-half the supply is not made available, there would be an advantage in constructing more reservoirs, not only at the sources of the River Bann itself and its other branches, such as the Rocky and Leitrim rivers, but at other sites along the course of the river where land is not valuable, to impound the surplus waters, as has been done to a limited extent in the case of the Corbet reservoir. Were such works carried out, about ⅗ths or ⅘ths of the annual flow might be conserved, and the water power not only made more valuable, but enough provided for a sanitary supply to the towns on the banks of the river, the most important of which are Banbridge, with a population of about 6,000, and Portadown, with one of about 8,000. The latter town, and the neighbouring low lands in the vicinity of Lough Neagh, have suffered much from long continued floods in wet seasons. Were reservoirs constructed on the other rivers flowing into Lough Neagh, and forming part of the general Bann drainage area, these floods would be much diminished, if not entirely prevented, for the Upper Bann's drainage area is only 134 square miles, or $\frac{1}{17}$th that of the Bann system. The largest tributary is the Blackwater river, with a drainage area of 626 square miles; the next, the Main river, with 277 square miles; next, the Balinderry river, with 166 square miles; next, the Upper Bann; and the Moyola comes very near it, with 129 square miles. It is singular that, for so far, reservoirs have not been constructed on these rivers. A consideration of what has been already done on the Upper Bann shows that much more good might have been done, and litigation prevented, had the river been under one general management, in which representatives of the different interests would have had a voice. The following interests should, I think, be represented; viz., landholders, millowners, Sanitary Boards, fisheries and irrigation. As an instance the Bann Reservoir Company, about the beginning of the year 1858, proposed to contribute largely to a scheme costing little money, by which the drainage of the River Muddock would have been much improved, and a large amount of land set free from floods, to which they were previously subject, but the landlords would not co-operate.

I hope this brief description of what has been already done on the Upper Bann river may induce other districts more generally to adopt reservoirs, and make the water supply a source of wealth and health to each district, instead of allowing it to become injurious, both to property and health, and in many cases destructive.

The Upper Bann was formerly celebrated for its trout-fishing, which has been much injured of late by the discharge of flax steep water and other impurities into its course. Salmon are now prevented from ascending the stream by the weirs; Eels can be taken largely during the floods, but are not much sought after. Pearls have been found in rare instances in the river. Its water is exceedingly soft (about 5° by Clarke's test) and peculiarly well adapted for bleaching, which is extensively carried on in the various linen establishments along the river.

NATIONAL WATER SUPPLY.

By J. Bailey Denton.

I duly received the circular of the 12th ultimo, inviting me to attend the approaching Conference of the 15th and 16th of May, and suggesting that I should furnish some further remarks on the subject to be discussed.

The introduction of the Rivers Conservancy Bill by the Lord President into the House of Lords, and the publication of the letter addressed by his Royal Highness the Prince of Wales to the Premier on National Water Supply, would seem to render it inopportune for individuals to offer any observations on the "division of England and Wales into districts for the supply of pure water to towns and villages in each district," until it is known how far the Government will initiate, and the Legislature will sanction, the rendering the control of rivers and watercourses subservient to the more important object of water supply.

I venture to express the opinion that, at the present juncture, the only way of bringing to a practical bearing the knowledge in possession of the country, and the evidence given before the several Royal Commissions and Parliamentary Committees on the subject of our water economy in its various phases, is to impress upon the Government and the Legislature that the obligation to provide potable water of unexceptional purity for towns and villages situate within river basins, ought to precede all other considerations in relation to the improvement of rivers and watercourses, and that any action taken for their conservancy must fail in this one all-important point, if it does not proceed upon such recognition. It will be observed that in the Bill now before the House of Lords no direct reference is made to water supply, although such is the reciprocal bearing of that object upon river conservancy, that it is hardly possible to deal with one in a comprehensive way, independently of the other, without some prejudicial effect.

The timely proposition of his Royal Highness that there should be a central permanent Commission, whose duty it would be to investigate and collect facts connected with water supply in the various districts into which the United Kingdom may be divided, "in order to facilitate the utilisation of the natural sources for the benefit of the country as a whole," must, I submit, commend itself to every one as supplying, in the most tangible form, the omission of the Rivers Conservancy Bill, to which I have just referred. The suggestion is the more apposite, as it comes at a time when the larger centres of population are not only providing themselves with water to the disadvantage of small towns and villages, but are rendering unfit for domestic use—by pollution—the waters they do not appropriate.

It is an incontrovertable fact that, inasmuch as all rivers are maintained by the outflow of springs issuing from the water-bearing strata, and by the natural conservation of the rainfall upon high uncultivated surfaces, it is not possible to raise water from subterranean sources, or to intercept water from high grounds for the supply of populations, without affecting the flow of rivers and watercourses, while it is equally certain that any acts of conservancy which may lead to the more rapid discharge of watercourses descending from the hills to the valleys, will prejudicially affect the local water supply of the districts through which these watercourses pass. At the same time, it is known to those who have carefully studied the earth's stratification, that such is the alternation of pervious and impervious strata throughout this country, that there hardly exists a river basin, wherein, by special works of combination or otherwise, towns and villages may not be economically served with water without any appreciable effect upon our river systems.

What is now wanted is the record, in an intelligible form, of such hydrogeological information as is already in the hands of the Geological Survey Department, to be supplemented from time to time with additional details. This would furnish the most useful data in the hands of any Commission which may, on the suggestion of H.R.H. the Prince of Wales, be formed, and would make every one familiar with the underground sources of supply.

DOMESTIC FILTRATION OF WATER CONSERVED IN TANKS AND CISTERNS.

By J. Bailey Denton.

There is no object connected with our domestic economy which has an equal influence upon health, and which is, or may be, brought so completely under our control, as water when once delivered to the dwelling, and yet there is nothing that really receives so little attention. Impressed with this, the author is desirous of placing before the public a very simple means which he has adopted, where all the water consumed by a household for any purpose whatever may be effectually filtered, let the quantity be what it may.

For drinking, cooking, and washing of the person, including that used in baths, all water which has been in any way collected and stored in either outside underground tanks, or open reservoirs, or in inside service cisterns, to which it may have been raised from tanks and wells, should be subjected to filtration through such material as will most effectually remove from it any putrescible matter. This is necessary, for the simple reason that although water delivered into a dwelling may be perfectly pure when it first enters either the open reservoir, or underground tank, or the service cistern, it undergoes deterioration directly it is stored. If it is collected in reservoirs or tanks outside the dwelling, sundry vegetable and animal matters are carried into them from contributing surfaces, and when there, undergo decay and putrefaction. Leaves of trees, living insects, and excreta of birds and insects, soot from chimneys, and various other substances of organic origin, too, are invariably to be found in all these receptacles. If it is stored in service cisterns inside the dwelling, though some of these substances may be absent, clouds of dust and myriads of minute insects rise in the air from the lower parts of all dwellings, and imperceptibly find their way through existing crevices and openings into such cisterns, and soon taint their contents. The effect of this condition on the health of those who drink stored water may be very slow when the constitution is robust, but with persons of weakly frames, and in times of illness, it must tell with certain injury.

The existence of these substances is shown in the shape of a filthy deposit, which will be found in all receptacles of stored water. A close examination of this deposit will prove it to consist for the most part of putrescible animal and vegetable substances.

To remove these drawbacks, and at the same time secure economy in the use of water, the author has devised a means by which the supply to all dwellings, whether they be the palace, the mansion, the public institution, the moderate-sized house of the middle class, or the cottage of the poor, shall not only recover the purity it may have lost by storage, but may reach a condition even superior to that which belonged to the water before delivery. This is done by subjecting all the water used in the dwelling to filtration through carefully selected aërated material as it flows from the service cistern, to be drawn off in various parts of the dwelling. The arrangement by which the author effects this object is exhibited on the Society's premises, and is so simple and certain in the performance of its duty, that no water can be used by either the cook, the butler, the housemaid, or the scullery maid in the mansion, or by the labourer's wife in the cottage, until it has passed through the filtering material, which is kept in an aërated condition by the automatic action of the filter, in spite of any neglect on the part of servants.

The Self-supplying Aerated Filter.

The filter is fixed under the cistern of the dwelling in as high a position as can be arranged; the higher it is placed the wider its use, and the greater the benefit obtained from it. The service pipe from the cistern becomes the feeder of the filter, and there being no other water used in the house than that which has passed through it, the whole is filtered as it is drawn.

The filtered water does not occupy the same compartment as that which holds the filtering material. The two are distinct from each other. There are, in fact, two compartments, an upper and a lower one, the former containing such a quantity of filtering material as will constantly cleanse the water used in the dwelling, whatever that quantity may be, and the latter holding only so much fresh filtered water as can possibly be required in the establishment at any one time. The capacity of the lower compartment is made, in fact, to fit the actual requirements of the household.

As the water is drawn off from the lower compartment to be consumed in the kitchen boiler, or to be used for baths or any other domestic purpose, an equal quantity is admitted to the filtering material in the upper compartment. This reciprocal action is effected by the use of a ball or float in each compartment, which, acting upon a single valve, regulates the influx. By shutting off the water when sufficient quantity has passed through the filter, an interim of time is gained to effect that perfect aëration of the filtering material which is the great object in view, for it is by the aëration which follows the passage of water through the material that any putrescible matter which may exist in the water becomes oxydised, and is rendered harmless.

No filter now in existence effects these objects with the same certainty and with equal effect upon large as upon small quantities. In most filters the material is constantly under water, and, therefore, not aërated, while those which aim at aëration very imperfectly accomplish the object upon a small quantity only. In the "Self-supplying Aërated Filter," the air circulates above and below the material, and as water is 800 times heavier than air, and air must necessarily take the place of the water in the material, as soon as the water has passed through it, a constant change of water for air, and air for water, is kept up.

It was this characteristic of the filter that induced the author to christen it the "Self-supplying Aërated (Oxydising) Filter." He prescribes no especial filtrating material, but leaves the selection to be governed by the character of the water in use. He himself has found that burnt earthenware, or stoneware, such as sanitary pipes are made of, broken small into a granular condition, and mixed with clean fine sand, forms the best material for ordinary use. He uses no other, though in certain cases animal or vegetable charcoal may be superior, if it is frequently changed, and never used a second time until it has passed through the fire again.

Care should always be taken to fix the filter within ready reach, so that the material can be examined, and removed, washed, and returned, or changed for fresh material, as often as necessary.

The "Self-supplying Aërated (Oxydising) Filter" has been patented more for the purpose of securing good workmanship in its construction, and proper skill in fixing it, than for any pecuniary advantage to be gained from the patent. And it is with the object of drawing attention to an important deficiency in our ordinary domestic arrangements that this paper is read, not with any idea of promoting the commercial success of a new invention. Messrs. Merryweather and Sons, of Long-acre, are the makers of the filters, and they supply them of a size and with the material suitable for all establishments and institutions, public and private, taking care that the filtered water compartment shall be of such a size as to meet all requirements, including baths and trade uses. For trade uses and for stables, the arrangement secures the best of water without any extra labour.

The advantages of the "Self-supplying Aërated (Oxydising) Filter" are:—

1st. That at a moderate cost all the water used in a dwelling, let its size be what it may, can be filtered automatically.

2nd. That the only attention required of those who use it is to see that the ball-taps are in good working order, and that the filtering material is washed or changed periodically. In many instances a filter may be used twelve months without requiring either washing or changing.

3rd. That the filtering material can be at any time examined, taken out, washed, and replaced or changed without any difficulty whatever.

THE WATER SUPPLY OF KINGTON AND NEIGHBOURHOOD.

By G. Foote, Medical Officer of Health for Kington (Urban).

I was for nearly five years Medical Officer of Health to the Kington Rural, as well as the Urban

Sanitary Districts. I now hold the latter appointment only.

When I was elected to the office, in April, 1873, the water supply to the several villages was, with one exception, as bad as could be. They were mainly supplied with water from the different streams which ran through or by them, all highly contaminated with sewage and other matters injurious to health; for the privies, where they did exist, were either situated over the ditches which emptied into the several streams, or actually situated over the stream itself, and that was the case in a number of instances. The first work that was done under my advice was to remove the privies, and have the ditches cleaned out; many of them were immense elongated open cesspools. Then, to have fresh privies constructed, with dry pits, or the earth system adopted; in all cases, free ventilation was secured. Then, to have wells sunk, both public and private, wherever convenient, and so doing away with the necessity of using the water from the streams for drinking purposes. The improvement in the health of the different localities was very marked.

The exception I mentioned is New Radnor, which, though a borough, is only a village. It is situated at the bottom of a gorge in Radnor Forest, and there is a rivulet of very pure water coming down the gorge; a pipe conveys the water to some of the houses, but it is inserted into the stream below the point where it receives the sewage from several cottages. The stream continues its course through the borough, and the water becomes more and more impure; but it is used freely for drinking purposes. Yet New Radnor was better supplied with fairly good water than any small town or village in the rural district. I proposed to make it perfect, which could have been done at a small cost. If the water were intercepted by a pipe, inserted some 150 yards higher up the gorge than it is, where the water is free from any contamination, and then conveyed to the top of the town, where a reservoir could have been constructed, perfectly pure water would have been conveyed to any part of any house in the borough by a continuous service. The plan was steadily and successfully opposed, and nothing has been done in the matter all these years.

In Kington, which is a small town of 2,000 inhabitants, there is a spring of exquisite water issuing from an opening in the rock at the base of Bradnor Mountain; a pipe conveys the water, which is forced up by a wheel-pump turned by water-power, to a tank situated at the highest point of the town near the church, whence it is conveyed by a continuous service to a part only of the town. The other houses are supplied from wells, the water from which is always more or less contaminated, especially so in some streets, as there are a number of cesspools in all directions.

There is enough water in the Radnor spring to supply a town three times the size of Kington, and I have for years endeavoured to persuade the town Commissioners to buy the water-works, and form large reservoirs for the benefit of the whole town; my proposal has never been approved, and last year a poll was taken, and the inhabitants, by a large majority, decided to have nothing to do with the scheme. Thus, in two places, Kington and New Radnor, which are exceptionally favoured by nature in the supply of exquisitely pure water, a large portion of the population refuse to avail themselves of it, preferring, for the sake of economy, using water sure to be more or less contaminated.

I have now stated what has been accomplished for securing good and wholesome water in this sanitary district. From my own experience, I do not think that small towns or villages should be supplied with water, which has been collected into a reservoir from the neighbouring district, either from one streamlet or many. Unless it could be carried direct from its source in a pipe to the reservoir, no streamlet can be free from matters injurious to health; it receives all the surface drainage from the fields, saturated with manure of various kinds; and, in the majority of instances, the drainage also from cottages, with the foul matters from piggeries, &c., and I do not believe in any method yet discovered by which water so contaminated could be filtered, so as to render it in any degree pure.

In nearly every village or its neighbourhood, well water can be obtained, and if there are no cesspools permitted within a certain area, the water, if the well is of any depth, is sure to be pure, as the earth itself is the only natural and pure filter.

When required, well water can be easily stored in a tank by a little mechanical contrivance, and so a continuous supply maintained.

SUGGESTIONS OF A STATE RECORD OF THE SURPLUS WATERS FLOWING FROM HIGH AND UNCULTIVATED LANDS.

By Charles Slagg, C.E.

Further facilities ought to be given to the sanitary authorities of small towns for combining to obtain the best supply of water within their reach and resources. When the sanitary authority of a small town calls for a report on the best means of procuring a supply of water, the engineer called in finds—or may, and in fact often does find—that his instructions are too limited to enable him to propound the best scheme, in point of quality, quantity, and economy of working. There are, in numerous instances, several small towns lying near together which have no supply of water, and which have separate sanitary authorities. Moreover, there may be, at no great distance from these small towns, a larger town which requires a further supply of water, or there may be—and in fact in one instance at least there are—two such towns.

To confine my remarks to cases within my own knowledge, there are three separate local authorities in a district comprised within a length of five miles and a breadth of two and a half miles, the aggregate population of which is 25,000. In this district there is no supply of water. At a distance off, there are two towns of a population of 40,000, taken together, and in each town the supply of water is very inadequate, the one in point of quality and the other of quantity.

Taking first the three smaller towns, each has its sanitary authority, and each has called for a report on the water question, there having been made three reports by different engineers. The instructions to each being limited to the requirements of the one place, the engineer finds it impossible to do more than recommend the best of the sources in the immediate neighbourhood, whereas if anyone of the engineers had been consulted jointly by the three Boards, he would probably have recommended a better plan in respect of the three requirements of quality, quantity, and economy of working.

If we now take into consideration the two larger towns also, both of which are seeking means of improving the water supply, but neither of which can do so from the present sources, there appears a further reason for a combination of towns for this purpose.

There is a range of hills the surplus waters of which would afford an ample supply to all the towns by gravitation. The distance is certainly considerable, but it would probably be found not too great for economy in a combined scheme. But when each authority considers its own scheme singly, it seems preposterous to go to such a distance, and, each authority acting without reference to the others, no one investigates the capabilities of the larger and better source.

What, then, ought to be done in all such cases? It should be, if this Conference think well to recommend it, that the utmost capabilities of all such sources to afford a supply of water to towns be investigated and declared. Then each separate sanitary authority would know how much water is within its command, and if, knowing these capabilities, the engineer should advise that it would be economical to make joint works, each authority would add to its share of the cost of the joint works that of its own service reservoir, branch main, and town piping.

An analogous precedent for such a record is the census of the population. When we want to know the population of a place, we do not, individually, count or estimate the number, but turn to the State record. So should it be with water. The capabilities of every area of high ground to afford water for towns should be recorded, both as to quantity and elevation, and all proper sites for storage reservoirs should be investigated, and measured as to their possible contents.

Some of these areas of high ground are already appropriated to existing supplies of water, but many remain unappropriated, either wholly or in part.

"ABYSSINIAN" TUBE WELLS.

By Robert Sutcliff.

The process of obtaining water by digging wells is of great antiquity, and that of boring scarcely less ancient. The particular method of obtaining water that it is the object of this paper to explain, is entirely modern. The crude idea of driving a tube into the ground for water is scarcely more than a dozen years old, and many of the appliances for driving tube wells are still more recent. In ancient days, wells were national property, and battles of possession have been fought over them. Now, a well can be made in many places in a few minutes, and the very deserts may be tapped, and clear springs obtained from them. Like many other clever inventions, the tube well owes its first existence to America, although it has been jocularly claimed as having been really originated by the negroes, who drove pointed bamboo canes into the earth, and slaked their thirst by drawing up the water through the pores of the cane. Be this as it may, the first iron tube wells could only be driven in the very softest soils, and the tubes were struck on the head, which caused bending, injury to the screw threads, and fracture of the pipes. The pipes at first employed were also of inferior quality, such as are used for gas purposes, and were quite unsuited to the rough treatment and vibration that a tube well is subjected to. Upon the introduction of the patent into this country, the necessity for an improved method of driving the tubes became at once evident to those having charge of the invention.

This process it may be of interest to describe. In the first place, the materials used must be of the very best quality, and specially tough and good iron is required for the tubes. The first tube is pointed and perforated up for a few inches, with holes varying from one-eighth to quarter inch. The point is somewhat bulbous, but only sufficiently so to make clearance for the sockets by which the tubes are connected together. On the tube a clamp is fastened, provided with steel teeth, so as to grip the tube. This clamp is tightened by means of two bolts. Next, a cast-iron driving weight, or monkey, is slipped on to the tube, above the clamp. The tube, thus furnished, is stood up perfectly vertical, in the centre of the tripod; ropes are made fast to the monkey, and driving is commenced by two men pulling the ropes, and allowing the monkey to fall on the clamp. It is particularly important that the bolts of the clamp are kept tight, so that no slipping takes place. When the pointed tube has so far penetrated the earth that the clamp reaches the ground, the bolts are slackened, and the clamp raised again some two or three feet. Length after length of the tube is thus driven into the earth, being connected together by socket joints. It will be noticed that the tube well proper is, therefore, self-boring, and that no core of earth is removed.

One of the first questions that will suggest itself to a thinking mind is, will not those small perforations be blocked entirely up by being thus forcibly driven through the earth. This was the American's first idea, and he provided a sort of sleeve, in the shape of a sliding tube over the perforations, to protect them from the earth. Experience, however, has proved this protection to be quite unnecessary. The perforations are made about four times as numerous as is necessary for obtaining a full flow of water from the tubes. Earth does find its way into the tube-well in pellets, like the casts from a worm; but some of the perforations are always left sufficiently open to allow water to pass into the well, and if the soil comes rapidly into the tubes, it is easily mixed with water poured down from the surface, and drawn up by ½-inch tubes, to which a pump is attached. To thoroughly clean and open the perforations, an ingenious contrivance has, however, been utilised. Long before the tube wells were invented, a pump was manufactured that, by lifting the handle, would allow the water to run out of the tail-piece, and thus prevent freezing in winter. This sudden liberating of a column of water that is maintained above its normal level, is the method which is employed to clear out the perforations of a tube-well. In skilful hands, the water can be kept in a state of agitation, being alternately allowed to press through the perforations, from the inside and from the outside; and before the whole column of water has descended to the level of the spring, it is caught up by the pump, and a fresh supply drawn into the tube. In this way the perforations are syringed, as it were, free from all soft obstructions, and the excess of holes over what is required, makes the closing of a few by grit which is too large to pass through, of no consequence. This action of the pump is not only useful in clearing the perforations, but in some soils it plays a most important part in the development of a supply. When all the holes are free, the fall of the column causes jets of water to disintegrate the earth, and by this means the finer and softer particles are pumped to the surface, and either an actual cavity is formed below, or, in gravel, a sort of filter bed is left, out of which all the sand within reach of the pump has been withdrawn. It should be stated, that the first presence of water in a tube-well is ascertained by an ordinary plumb-line, which is also useful for gauging the quantity of earth in the tubes. Having got the tube-well into the spring from which it is to draw the perforations all free, and the earth thoroughly disintegrated in the immediate neighbourhood of the point, it remains to describe the method of pumping.

Until this plan of obtaining water was discovered, all pumping was done by means of a suction-pipe communicating with the well or bore-hole. As the atmosphere had free access to water in the well, the action of the pumps was simply to draw water out of the reservoir, and there its duty ended. The method of pumping a tube well is entirely different; all atmospheric pressure on the water in the tubes is removed at each stroke of the pump, and hence the supply is drawn to the spot, instead of simply flowing there by gravitation. Although the tube wells achieve this result as it were by accident, the importance of the fact is now generally acknowledged by engineers. Many engineers were of opinion that it would be impossible to obtain water at all, if the atmospheric pressure were excluded from the well, but they did not pursue their reasoning quite far enough. It is true there must be atmospheric pressure somewhere on the water that we pump from, but it need not be in the immediate vicinity of the well. Perhaps it is miles away. Pumping in this way, we have not the tiny reservoir of an artificial well, but in some cases natural underground lakes, one might almost say, seas of water, to draw from. Some here may recall how our army, during the Abyssinian war, was supplied with water by these tubes, and it was the prominence which that war gave to the invention that led to the present prefix to their name. For campaigning purposes the wells were only used singly, as one or two were found sufficient to supply the wants of a number of troops. When however large supplies for manufactories, towns and villages were needed, a fresh development in the system took place. Instead of single wells of great diameter, groups of moderate size were driven and coupled together by horizontal mains, so that powerful steam pumps could draw from many wells at the same time. The great friction that would be caused by drawing an enormous body of water to a single spot is thus avoided. Wells so coupled draw from a very large area of ground, and the water-level at any one spot is not so rapidly lowered. The very action of the pump, too, in drawing the water to the wells, opens and maintains channels of communication which help to keep up the level of the water. In putting down plant for a large supply of water, a trench hundreds of feet in length, and some two or three feet in depth, is dug, and tubes are driven every twenty-feet, and coupled by mains as already described.

It may be interesting to refer to some particular instances, where large supplies of water are thus obtained. At West Thurrock, in Essex, a cement company is pumping from two 5-inch tube wells, about 80 feet deep, 220,000 gallons per day of 10 hours. Another cement works at Northfleet is pumping 60,000 gallons per day. These have been pumped daily for about four years, and still give a constant supply. As expense is an important feature, it may be mentioned that the cost of these did not exceed £60 each. The coupled tube wells are to be found in greatest numbers at the centres of beer manufacture, where abundance of pure and cool water is an absolute necessity. At Burton-on-Trent, about two million gallons are pumped daily from these wells.

A feature of particular interest to this Congress is the question of purity of water supply. Tube wells very soon attracted the attention of sanitarians, from the fact that, being forcibly driven into the earth, there is little or no possibility of their being contaminated by surface drainage. Too frequently a dug well, from defective steining or other causes, becomes little better than a cesspool. It is also often expensive work to dig through water which is impure, in search of pure springs below, and still more costly, when the good water is found, to keep the bad from mixing with it. Accidental and temporary contaminations are not infrequent in dug wells. One of recent date came to the author's knowledge, which was of so serious a nature, as to cause a Government inquiry. It was found that in a certain district, supplied by a water company, enteric fever was raging with great virulence. No less than 352 cases occurred in places supplied with this particular company's water. In a very exhaustive report to the Local Government Board, it was clearly proved that a contamination of the wells, caused in a peculiarly offensive and direct way, was the origin of the epidemic. The instances of tube wells having been driven through contaminated water, and tapping pure springs below, are very numerous. A few may be mentioned, where the results are not merely one of opinion, but are proved by analysis. At Gravesend, within a stone's throw of the Thames, a 2-inch tube was driven through contaminated water, and reached a spring at about 50 feet, from which a sample was taken, and submitted for analysis. The analyst, after enumerating the particular constituents of the water, pronounced it to be the purest he had ever analysed, with the exception of Loch Katrine. Bear in mind that this was taken from a well situated in the last place one would expect to find pure water, namely, within a few yards of the River Thames, which at that point is quite salt, and charged with London sewage. A point has sometimes been raised, as to whether water obtained from such positions is likely to remain pure when regularly drawn from, and, perhaps, severely taxed. This particular well has been made between four and five years, and subsequent analyses have proved the maintenance of its good qualities. It is used for purposes which necessitate a very strict watch over its excellence. The ships at that port fill their store tanks from this well, the Royal yacht among the number, the quality of the water is not therefore taken for granted.

At Deal, another illustration of the perfect isolation of a spring was afforded. Most of the wells in that neighbourhood are brackish, and a supply of fresh water was needed for a flour-mill and for domestic purposes. Within the first 25 feet water was found in gravel, but too salt for use. The miller was under the impression that if the tubes were driven deep, fresh water would be obtained, and he discouraged any further testing of the water on account of the delays in so doing, until 100 feet had been driven. At 117 feet the pump was again applied, but instead of being better, the water was as salt as brine. The engineer having charge of the work noticed that at the depth of 45 feet the water level differed both from that at 25 and that at 117 feet, and the fact suggested to his mind the desirability of testing the quality of this middle spring. A second tube was therefore driven to 45 feet, and from it quite fresh water was obtained. This happened five years ago, and the water still remains free from brackishness.

Hundreds of other instances might be mentioned, but these are so marked as to be sufficient for the purpose of illustration.

Some waters of good quality, but containing sulphate of lime, &c., are much injured by the exposure they get in ordinary wells, and the author has heard of dug wells at Burton-on-Trent, that emit an unpleasant effluvia, and get unfit for use if not constantly pumped. This appears, therefore, an additional reason for keeping the atmosphere from the spring.

When rock, solid stone, or incompressible clay is met with, a tube cannot be driven through it without first making a hole, and removing the cores. In some cases, however, there may be many feet of loose earth which can be easily driven through; this (especially if gravel has to be passed through) is a tedious process. The tubes, therefore, may be fitted with a temporary hard wooden point, which will allow them to be driven through the soft earth, and when an obstruction that cannot be penetrated is met, the point is knocked out, and, being wood and in sections, it floats to the surface of the water, and leaves an open-ended tube, through which ordinary boring tools can be passed to chisel and break up the rock. A tube can frequently be driven through gravel and clay to a depth of, say, 70 feet in a single day. To bore to the same depth in similar stratum frequently takes ten days or a fortnight. The saving that may be effected by driving through the loose stratum can, therefore, be readily appreciated, and, what is still more important, the upper part of the tubes are fixed more tightly in the ground than if a boring had been made to receive them. In some cases, however, hard strata come right to the surface, and the boring operations, consequently, cannot be deferred. When this is the case, instead of using a pointed tube, an open-ended steel shod pipe is driven into the hole as the boring proceeds. As the tools pass down inside the pipe they do not cut so large a hole as the outside circumference, and some little trimming down of the sides is left for the steel shoe to perform.

In great depths the single tier of pipes, with which the work is commenced, cannot be forced the whole way. Tubes, therefore, of smaller diameter are inserted; but, as to pump by the tube well method, air-tight joints are absolutely necessary, the final tube is continuous from the deep spring to the surface. In this way, tube wells 300 and 400 feet in length are put down, and if the spring, when tapped, rises to the surface, or within, say, 25 feet of it, only an ordinary lift-pump is required to obtain the supply. Where the water does not rise to the required height, a deep well pump can be lowered into the tube well, and worked by rods from the surface.

Bored tube wells are frequently put down in sets, and connected by horizontal mains, where large supplies are required.

The new water-works at the town of Skegness, in Lincolnshire, will be supplied by two bored tube wells thus coupled together. These wells are already completed, and a supply of pure water from the sandstone has been obtained, although salt water was passed-through during the upper portion of the work.

In describing the method of driving tube wells in the commencement of this paper, mention has not been made of the latest system, which is more particularly applicable to tubes of large size. It is so simple as to merit a brief notice. An elongated cylindrical weight passes down inside the tube, and the blow, instead of being struck at the surface, is delivered where it is wanted, near the point which penetrates the earth. As water in the tube would impede the force of the blow, the first socket above the perforations is made sufficiently long to admit of a stout iron ring or washer being placed in the centre of it, in such a way that the two lengths of tube, when screwed tightly together, butt against it, one on the under and the other on the upper surface. The interior of this ring is of sufficient size to allow the water to pass freely through it, but it has a screw thread cut throughout its whole length. During the operation of driving, the opening in this ring is closed by a steel plug, which is screwed down into it until its shoulder butts on the ring. The upper surface of the plug forms an anvil, on which the driving weight falls. The plug is readily removed and brought to the surface when the required depth has been reached.

The object of this paper has been to describe a particular method of obtaining water in large quantities, and free from contamination; but in the great question that this Congress is considering of National Water Supply, no one system can, under all the varying circumstances, be applicable. One town may have abundance of good water at its feet, others may have to seek it and conduct it from a distance.

The collection of full information on this part of the subject is of the greatest interest and importance, and before a really national scheme of water supply is entered upon, it seems advisable that a complete hydrogeological survey of the whole country should be carried out.

Mr. Joseph Lucas, has, for some time past, devoted special attention to this branch of geology, and has, single-handed, mapped out certain districts, and compiled much information into a compact and useful form. To carry out such a gigantic inquiry in a reasonable time, however, requires more assistance than a private individual can generally command, and, probably, it is in this direction that Government aid might, in the first instance, be most advantageously directed.

EVILS OF IMPURITY, AND CONSEQUENT CONNEXION OF THE QUESTION OF WATER SUPPLY AND SEWAGE.

REMARKS ON SOME OF THE DISEASES DUE TO SEWER-GAS POISONING.

By John Brown, L.R.C.P., London, &c.,

Officer of Health to the Bacup Urban Sanitary Authority.

During the summer and autumn of 1878, I made a large number of observations on the effects of breathing an air contaminated by sewer-gas. I have notes of thirteen houses in which drain diseases existed, and in which there were grave sanitary defects, such as ought to have attracted the notice of the householders. Unfortunately, the public are very careless on these matters, especially the working classes. Happily, there are signs that the more educated are becoming alive to the vital importance of pure air and water. In seven houses the slop-stone pipe was untrapped, and went straight into the drain, and from which there arose bad smells, especially in the summer. In the remaining six there were untrapped and rubble drains (not ventilated) which were close to the door of the house, or passed beneath the floor.

The following are the diseases observed:—

A. *Inflamation of the Lymphatic Glands*, more commonly the cervical. As a rule the glands are not acutely inflamed. Every case was among young children; they are obnoxious to it.

B. *Abscesses.*—In some cases the inflamed glands suppurated. The abscesses are generally chronic and almost painless. These, too, are more common among children. The abscesses may form in any part of the body. The following were observed:—*a.* Submaxillary abscess; *b.* Cervical; *c.* Axillary; *d.* Inguinal; *e.* Facial; *f.* Pelvic; *g.* Multiple abscesses; *h.* Temporal abscess.

C. *Diarrhœa.*—Sewer-gas is probably a fertile source of summer diarrhœa, especially among infants and young children, who live in unsanitary houses. The diarrhœa is very difficult to cure, and often ends fatally. In some cases there are other conditions, such as bad feeding, which tend to keep up the disease.

D. *Sore Throat.*—In one house there were three cases of sore throat in adults, and one child suffering from diphtheria. The child died and the adults recovered. It would appear that the poison which caused diphtheria in the child, caused sore throats in the adults.

E. *Typhoid Fever.*—Though I have included this among drain diseases, yet I would not affirm that it can be generated *de novo* from sewer-gas. In two cases there were probabilities that the germs of typhoid fever may have been latent in the sewers for years. In one case, however, it was impossible to trace the origin, or to suggest the cause, except the sewer-gases.

F. *Puerperal Fever.*—I have observed several cases in unsanitary houses. I believe a parturient woman runs a great risk of septicæmia if delivered in an air contaminated with sewer-gas.

G. *Anæmia.*—This is found more often among children and young persons.

H. *Nausea, Languor, and Headache.*—The symptoms are not uncommon among adults, generally women. These symptoms are so markedly due to bad smells, that the patient will often suggest it as a cause.

All the above diseases may be due to other causes, and it is possible that the detection of foul smells in houses with these diseases may be a coincidence. The following will help us in forming a diagnosis. If two or more persons in a house are suffering from summer diarrhœa, chronic abscesses, enlarged cervical glands, we may suspect sewer-gas poisoning. Medical treatment is often ineffectual until the patient is removed into a healthier atmosphere, when a speedy cure follows. In the winter, when the decomposition of sewage matter is far less active than in the summer, I have found that infantile diarrhœa and chronic abscesses are very few when compared with the number seen in the summer.

Sewer-gas is especially dangerous to young children. Of 25 persons suffering from sewer-gas poisoning, 17 of these were under 16 years of age. Older persons are not so soon affected; in them it often causes anæmia, languor, nausea, and headache. The following gives the diseases found in each house, with ages of the patients, and probable source of the sewer-gases:—

House No. 1. *Submaxillary abscess*, and *enlarged cervical glands*, in children aged two and five years respectively. There were untrapped slop-stone, and bad smells from a rubble drain.

2. *Cervical abscess* in a child, aged nine years, probably due to bad smell from defective drain.

3. *Axillary abscess* and "*summer-diarrhœa.*"—The child, aged five years, also had other enlarged glands in the axilla and elbow. Diarrhœa occurred in a patient aged six weeks. Another child had recovered from a submaxillary abscess. There were bad smells from untrapped slop-stone and defective drains.

4. *Two cases of inguinal abscess* and *summer-diarrhœa.* One of twins died from exhaustion, due to inguinal abscess, and the other from diarrhœa. The mother recovered from *inguinal abscess*, the cause being sewer gas from an untrapped slop-stone pipe.

5. *Facial abscess* in a girl, aged nine years. This was probably due to sewer-gas from an untrapped slop-stone pipe.

6. *Pelvic abscess*, and three cases of "*summer-diarrhœa.*"—A patient had been confined six weeks. She was very anæmic, and had no appetite. This was due, undoubtedly, to the bad smell in the house. She was taken ill with an abscess in the pelvis. Just at the same time there were three other cases of summer diarrhœa in the house. The infant died. For the sake of the woman, I recommended that the family should remove at once, which they did, and the patient made a good recovery. The abscess discharged itself *per vaginam*. The cause was a defective privy, from which there was a continual leakage of fæcal matter into the house.

7. *Multiple abscesses.*—A baby, aged six months, had twenty abscesses, scattered on its legs, arms, and body. This state was due to bad emanations from a defective privy. The privy was at once altered at my suggestion, and the patient speedily recovered.

8. *Temporal abscess* in a patient aged eleven years. The cause was foul emanation from a defective drain.

9. *Typhoid Fever.*—A death from typhoid fever being reported to me, I inspected the house, and found that bad smells came from the untrapped slop-stone pipe.

10. *Typhoid Fever.*—Another death from typhoid fever was reported. On inspection, I found the slop-stone untrapped, and an untrapped drain close to the door.

11. *Typhoid Fever.*—This was a case of typhoid fever in a gentleman living in a new, well-built house. On inspection, I found the drains and slop-stone trapped. The wife, however, complained of bad smells coming from the water-closet, which was on the first-floor. The water-supply in the summer being limited, the drain would not be well flushed. The mephitic gases, generated in large quantities in hot weather, would soon saturate the water in the pan of the water-closet, and pass into the house. The drain was long and unventilated; and the sewer-gases, being of lighter specific gravity than the air, would seek an outlet at the highest elevation, which would be the water-closets. The drain has since been ventilated. The patient died.

12. *Diphtheria*, and three cases of *Sore Throat.*—A child, aged three years, had diphtheria, and died in three days. In the same house, there were three adults suffering from sore throats, all of whom recovered. I found that there was a bad smell from untrapped slop-stone.

13. *Puerperal Septicæmia.*—The third day after confinement, the patient had usual symptoms of septicæmia. She nearly succumbed two or three times. After about five weeks, she had a relapse, which proved fatal. In this case there was a foul smell from an untrapped drain, within a few feet of the door where the patient was confined.

THE RECENT OUTBREAK OF ENTERIC FEVER AT CATERHAM AND REDHILL.

By R. Thorne Thorne, M.B. Lond.; F.R.C.P.

At the request of the Society, I herewith submit a brief account of the circumstances under which an extensive epidemic of enteric fever has recently arisen, in and near the towns of Caterham and Redhill. Having already prepared a detailed report as to all the circumstances of the epidemic, and this report having been publicly issued by the Local Government Board, I propose here to confine myself to such a *résumé* of the facts ascertained, as may serve to form the basis of a discussion, which I am informed the Society desires to entertain on the present occasion.

During the fortnight ending February 2nd last, enteric fever broke out at Caterham, Redhill, Earlswood, Bletchingley, and Nutfield, in the county of Surrey. The outbreak appeared almost simultaneously in Caterham and Redhill, the attacks commencing in the one town only a few hours after they were heard of in the other; and within a few days cases also came under treatment in the other places named, the total number of attacks reaching 196 during the fortnight referred to. Here were a series of outbreaks almost simultaneous in their incidence upon a series of towns and villages, which were situated at distances varying from about three to ten miles apart, and which were all ascertained to have been, for a long time, remarkably free from the disease by which they were now attacked. And in view of the facts ascertained during the early stages of the inquiry instituted, there appeared the strongest grounds for concluding that the several outbreaks in the several localities constituted one epidemic, and that they had one common origin. The period of incubation in enteric fever being about, or somewhat under, a fortnight, these 196 cases could be made the subject of inquiry, with regard to causation, apart from any source of error which might be due to the spread of infection by means of any of the earlier attacks in the same epidemic.

All the sanitary circumstances of the populations affected were minutely investigated, the inquiry in this respect including, though being by no means limited to, all the conditions which previous experience had shown to be related to the prevalence of this disease. The various systems of sewerage and drainage, the several means of excrement and refuse disposal, and the numerous milk services, were in turn dealt with; but not only could nothing be ascertained with regard to them which had any bearing upon the epidemic, but none of the affected localities had anything in common with respect to any one of these conditions.

There was, however, one condition which the several towns and villages where the disease prevailed had in common; they all derived their water-supply from the same source, namely, from the works of the Caterham Waterworks Company. And not only so, but it was ascertained that among the occupants of over 1,400 houses, within the infected district, to which the Company's supply was not delivered, no persons who had not consumed this water were affected, and also that from amongst those who habitually used other supplies, the disease had specially attacked the few who had been recent and occasional partakers of that derived from the Company's mains. The suspicion, however, which under these circumstances naturally attached to this water, received no support either from consideration of the source whence it was derived, namely, the chalk wells, more than 500 feet deep, sunk at the southern extremity of the high-lying ground which bounds the Caterham Valley on the west, nor from the history which had attached to its previous use, and which, in point of wholesomeness, had won for it a deservedly high reputation. But the evidence which associated the spread of the epidemic with the consumption of this water gradually became overwhelming, and hence everything relating to its sources, storage, and distribution was, with the ready co-operation of the Company's officers, carefully inquired into.

The possibility of soakage of filth into either of the wells from cesspools, had, even prior to the occurrence of the epidemic, attracted some attention. But, although the steadily increasing practice of fouling the chalk, in various parts of the Caterham Valley, by means of cesspool soakage, is one which can hardly fail, before long, to constitute a source of danger to the water services deriving their supply in this locality from this stratum, if indeed it does not do so already; yet it appeared obvious that the epidemic in question had not been brought about in this manner.

Amongst the many other points investigated, was the possible occurrence of any contamination of the water in the mains, owing to the suction of foul air or other matters into them, during periods of intermission. But no such intermissions had occurred.

Circumstances had, however, in the meantime come to my notice, which led to the inquiry as to the cause of the contamination of this water-supply being extended in another direction.

During the latter part of 1878, and the beginning of the present year, the Caterham Waterworks Company constructed an adit from one of their old wells up to a new bore, which had been made for them by the Diamond Rock Boring Company, and which was at the time approaching completion. This adit is situated in the chalk at a depth of 455 feet. It measures 6 feet by 4 feet, and is 90 feet in length. A number of men were employed in this work, some of them being in the well below, others on the surface. Inquiry was made as to whether any of the men had ailed whilst at work, and it was ascertained that one of them, who left work some time in January, was believed to have been ill, although no inquiries had been made concerning him since he quitted the works. This man was found out, and the history obtained, both from him and from his wife, can leave no doubt but that he had recently suffered from enteric fever. Indeed, it was ascertained that, though continuing at his work in the adit below, he was, from about January 5th until January 20th, when the severity of his symptoms confined him to his bed, the subject of a mild though marked attack of enteric fever, which was accompanied with such profuse diarrhœa that, notwithstanding certain regulations to the contrary, he was compelled to evacuate in the adit "at least two or three times" during each shift. The exact method by which his poisonous evacuations found their way into the water is a little uncertain, but even assuming the absolute truthfulness of his statement to the effect that a pail which was constantly being drawn to the surface, was invariably resorted to as a closet, there were ample means, on his own showing, by which the well-water could have been contaminated by them. Within 14 days of the commencement of his purging, the disease broke out in an epidemic form, amongst the consumers of the Company's water.

Confirmatory evidence as to the nature of the man's illness was obtained, when it was ascertained that on the previous December 25th, 26th—the exact date when his disease, if enteric fever, must have been contracted—he had been away from Caterham, and had stayed in a town where that disease had been somewhat prevalent.

In short there can be no doubt that the pollution of this water, as the result of the man's disease, and the epidemic in question, were related to each other as cause and effect; indeed the several essential incidents recorded are linked together in point of date, with a precision characteristic of the results which might have been expected to have followed a scientific inoculation.

One additional circumstance bearing upon the correctness of the view I have expressed, may be noted. The village of Warlingham, where the Caterham Company's water is laid on to as many as 156 houses, exhibited an immunity from the epidemic. But at the precise period when the Caterham water must have been most potent for harm, some 12,000 gallons a day of an altogether different water was, owing to a temporary emergency, pumped into the main that supplied that village.

As soon as the main facts of the epidemic had been ascertained, the inhabitants of the affected district were, by public notice, cautioned against the use of the Caterham water, and steps, including the copious use of disinfectants and long continued pumping to waste, were taken by the Company to get rid of all possible contamination. The efforts in this direction appear to have been thoroughly successful, for the epidemic soon ceased, and it has not been renewed, although the water has again been brought into general use. The total number of cases, however, which were reported to me at the time, and which have since been heard of, cannot fall short of 370. By far the majority of attacks were of an unusually mild type, and the fatal cases were limited to 21.

Amongst the points deserving special notice in connexion with the circumstances of this epidemic, I would suggest the following:—

1. That the view, to the effect that even a comparatively minute quantity of the poison contained in the evacuations of enteric fever patients may, when subjected to conditions favourable to the development of that poison, lead to the specific infection of very large volumes of water to which it has gained access, is fully borne out.

2. That a special danger attaches to the prevalence of the mild—or, as they have been termed, "perambulatory"—cases of enteric fever, by reason of the intensely poisonous nature of the diarrhœa which characterises that disease.

And having regard to these facts:—

3. That all possible sources of excremental contamination, in the vicinity of water-sources, should be rigidly dealt with

4. That care should be taken, in connexion with works for the construction or storage of water, to exclude from employment all persons suffering from any diarrhœal affection.

MEMORANDUM OF RECENT EPIDEMICS PRODUCED BY POLLUTED WATER SUPPLY.

By Ernest Hart.

(Chairman of Council of the National Health Society.)

The accompanying summary contains the facts as to the causation, progress, and fatality of epidemics of a certain class of zymotic disease, in England, which have been proved by official investigation to have been due to polluted water, since the passing of the Sanitary Act, 1866.

The summary has been limited to cases which have been investigated by the Medical Inspectors of the Privy Council and of the Local Government Board, (1) because it is believed that all, or nearly all, the considerable epidemics caused by bad water since 1866 have been investigated on behalf of the Government, and (2) because it is only in these official reports that the facts as to causation, progress, and dimensions of epidemics are fully and accurately stated. An examination of some hundreds of outbreaks unofficially reported during the last twelve years, says that for the most part they have not been investigated with the required accuracy.

The summary, which has been compiled with considerable labour, refers, it will be observed, to epidemics of enteric fever only. Cases have arisen in which outbreaks of scarlatina and diphtheria appear to have been connected with impure water; but as this connection is merely hypothetical, it has been judged best to omit any reference to the outbreaks in question.

It need hardly be stated that the chief causes of the spread of enteric fevers are excremental pollution of the air or water, or of both. In epidemics occurring in towns which have a common water supply, the influence of the water in the propagation of the disease can be accurately measured. But where, as is too often the case, enteric fever breaks out in a place whose only water supply is from private wells, and whose only system of excrement disposal is by means of privies, it usually becomes quite impossible to say how much of the epidemic is due to the polluted water, and how much to the fouling of the air from infected privies. Doubtless, soakage from the privies into the wells is mainly the cause of the spread of the disease; but investigators have, in the vast majority of cases of this sort, been baffled in assigning the precise cause of the outbreak, because every condition favouring its origin and spread existed in abundance at the place.

In the admirable series of Reports on the Public Health, published under the direction of Mr. Simon, instances of outbreaks of this kind are to be found by the hundred. Such of these as have produced the most definite results as regards water, are recorded in the summary; but it must be remembered that there are very many more in which water, though it played an important part, was not alone concerned in the propagation of the epidemic.

It is impossible to make any sort of estimate of the number of lives annually sacrificed in this country at the shrine of polluted water. But the deaths must represent a very considerable proportion of the fatality from enteric fever, to say nothing of other diseases. When it is remembered, that in 1877, no less than 6,879 entirely preventable deaths occurred in England and Wales from this one disease alone, and that thus, in one year, some seventy thousand people were caused needless suffering and anguish, through the ravages of a disease intimately connected with filth, it will be seen how great a stake England has in the maintenance of the purity of its water.

The doctrine that a vast influence is exercised over the health of communities by the quality of water which they consume, is one, says Mr. Simon, "which, as far back in literature as any reference to such questions could be expected to exist, may be seen to have universal medical consent in its favour. During long ages of history, the common instincts of mankind were even surer and stronger than undeveloped science could be, in revolting against the use of unwholesome waters. For instance, among the lessons which survive in modern times from the wonderful intellect and vigour of ancient Rome, the frequent far-reaching aqueducts, which record an unbounded care for the provision of proper urban water supplies, are monuments kindred in spirit, and only second in dignity, to the consummate system of jurisprudence of the same singularly organising people." Of the many invaluable additions and improvements which medical knowledge has received during the last thirty or forty years, scarcely any can be compared for present practical importance to the discoveries which have given scientific exactitude to parts of the doctrine so ably referred to by Mr. Simon. The connection between impure water and diseases, although amply proved, does not rest on so exact an experimental basis as could be desired, probably on account of the imperfections of our present modes of analysis of water. Moreover, the evidences of this connection differ very much

EPIDEMICS PRODUCED BY POLLUTED WATER SUPPLY.

Place and Reporter.	Date of Epidemic.	Exciting Cause of Outbreak.	Circumstances of the Epidemic.	No. of Cases.	No. of Deaths.
1. Baldock (Herts). Population, 2,000. Dr. Thorne Thorne.	1873-4. Sept.—April.	Water supply from wells in chalk, obviously polluted by cesspools. Outbreak of enteric fever occurred, when considerable disturbance of the polluted strata through which water supplying wells flows, was occasioned by construction of new sewers.	Spread of disease favoured by numerous accumulations of house refuse and over-crowding.	60	3
2. Bedale (North Riding). Population, 1,000. Mr. W. H. Power.	1877. July & Aug.	Case of enteric fever introduced into house when all the conditions for its spread—polluted water, bad drainage, bad excrement disposal, and nuisances—existed.	Precise channel of infection doubtful, but 15 out of 20 families invaded obtained their water from a well to the trough of the pump of which all kinds of foul matters (*e.g.* tools and barrows used in emptying of privies), were brought for washing.	36	5
3. Bourton-on-the-Water (Gloucester). Population, 1,109. Dr. Ballard.	1874. June—Oct.	Evacuations of a typhoid patient cast into a privy which overhangs a stream which supplies many of the villagers with water. Wells commonly in dangerous proximity to privies and drains.	First cases occurred amongst persons drinking the water from the brook. Subsequently epidemic spread throughout the village, because of pollution of local wells by experimental matters from cesspits, containing the evacuations of persons who had suffered from fever, and also by soakage from drains and from brook.	137	4
4. Bradford (Wilts). Population, 7,000. Dr. Thorne Thorne.	1877. April—July.	Water supply of town derived from springs cropping out of the Oolite, the water being procured from wells or reservoirs constructed in the rock. Through fissures in rock the liquid filth of place has long penetrated, till all the supplies of water must be more or less fouled. A case of enteric fever at the "Chantry," under the foundations of which springs flowed, which must have received pollution by soakage from an old stone sewer.	Springs flowing under "Chantry" supplied two houses and a public tap, frequently resorted to by children from a neighbouring school. Twenty children residing in different parts of the town, but attending this school, were attacked by typhoid fever, other cases amongst persons using the tap, and at the private houses to which water was supplied. Closing of tap followed by cessation of epidemic amongst school children. In other parts of town disturbance of soil for sewerage purposes helped on the epidemic.	50—60	8
5. Caius College, Cambridge. Dr. Buchanan.	1873. Nov. & Dec.	Contamination of a particular section of the college water service (by the entrance into it of air charged with the contagium of enteric fever) during a period of intermission.	The epidemic was mainly confined to a particular court, in which it affected all the levels and staircases. It began a fortnight after the intermission of supply. Water-closet air shown to have had direct communication with the water-pipes.	15	[?]
6. Dewsbury, Batley, Heckmondwick, & Ravensthorpe (York). Dr. Thorne Thorne.	1877. Jan.—April.	Believed to be the pollution of the (joint) water supply of these towns at the gathering-ground prior to its delivery to reservoir. One of the streams feeding the reservoirs found to receive drainage of farm-house, stables, cow-house, &c. Suspicious surroundings moreover of conduit from gathering-ground to reservoir. [No other explanation possible.]	Inquiry made too long after epidemic to make the fact of specific pollution of water sure. But enteric fever appears to have attacked at first only people using the water. Epidemic subsequently spread by intermittent water service, allowing suction of tainted air into mains, and by the defective conditions of sewerage and drainage by excrement disposal in the district. Epidemic commenced in each of the districts at the same time, though each had a separate delivery main.	Circa 600	65
7. Guildford (Surrey). Dr. Buchanan.	1867. September.	Houses in a certain part of the town exceptionally supplied on a particular day with water from a high-standing reservoir previously filled from a new well. This well sunk through a porous stratum of chalk, and in close proximity to various sewers, one of which was found to leak in several places.	Epidemic almost exclusively confined to the part of the town corresponding with the particular section of the water supply. People of all classes infected.	264	21

8. GUNNISLAKE (Cornwall). Dr. T. H. Bloxall.	1875. Sept.—Nov.	Evacuations from a man coming into the district with typhoid fever thrown on a dirt-heap, near to an adit feeding a reservoir which supplied the town. Porous soil, steep gradient, and heavy rainfall, doubtless caused specific infection to be communicated to water in adit.	Outbreak confined to area supplied with water from reservoirs. Of 1,916 partaking of water, 138 were attacked. Of 1,085 supplied from other sources, 5 only attacked.	143	6
9. HAWKESBURY, UPTON (Gloucester). Dr. Ballard.	1872. Feb.—Aug.	Village stands on fissured Oolite, into the fissures of which are discharged the excremental matters of privies, so that privies very rarely require emptying. Into the same rock are sunk the wells, which have been for a long time polluted by the cesspools.	A case of enteric fever, introduced at the top of the village, spread through it by the medium of the privies and wells. It went right down the village to the end.	113	14
10. HUCKNALL TORKARD (Notts.) Dr. Harries.	1872. July & Aug.	Immense rainfall flooded privies and middens, and washed their contents into the wells and streams affording the water supply of the population.	Epidemic spread by impure air, damp houses, &c.	100	10
11. LEWES (Surrey). Dr. Thorne Thorne.	1874. July—Dec.	Pollution of a stream occasionally used for the water supply of Lewes by the river into which the town sewage is poured.	The epidemic commenced at an interval corresponding to the incubation period of enteric fever from the date when the water from the stream was used. It was subsequently spread by the suction of infected air into the mains from water-closets during periods of intermission.	486	37
12. LOWER GORNAL (Staffordshire). Dr. Ballard.	1873. Aug.—Dec.	No drainage; well water very bad; many persons resorted to springs polluted by sewage from privies.	Epidemic spread through the medium of infected privies, but the principal agents were waters of wells and of the "springs" polluted with infection of enteric fever.	700 (Estm.)	34
13. NUNNEY (Somerset). Dr. Ballard.	1872. July—Oct.	Brook water used by villages for drinking purposes. The evacuations from an imported case of enteric fever found their way into the brook.	Epidemic attacked water drinkers more especially. When unpolluted water was brought into the village in carts, epidemic ceased.	76	[?]
14. OVER DARWEN (Lancashire). Dr. Stevens.	1874. Oct.—Dec.	Pollution of water conduit (supplying Darwen) with enteric fever poison, from drain which ran over conduit, and which, imperfect itself, allowed filtration into conduit through the imperfectly secured points of joints.	Epidemic was sudden, and well nigh universal, affecting people living in all parts of the town, and variously circumstanced as the local filth conditions.	2,035	104
15. REDHILL & CATERHAM (Surrey). Dr. Thorne Thorne.	1879. Jan. & Feb.	Pollution of the deep wells of the Caterham Water Company with the specific infection of enteric fever, imparted to it by the evacuations of a workman suffering from that disease, who was engaged in one of the adits of the wells.	Epidemic attacked exclusively (except a few secondary cases at end) persons using the water. Populations with other supplies entirely escaped. Man was engaged in well from Jan. 5—20, and after a fortnight's interval, the attacks commenced to occur; after man ceased work, attacks began to die away.	352	21
16. SHERBORNE (Dorset). Dr. Bloxall.	1873 Jan.—May.	Pollution of water supplied by local authority with infected air sucked into pipes from closet pans during intermission of supply.	Epidemic attacked almost exclusively persons drinking town water.	243	13
17. TERLING (Essex). Population, 900. Dr. Thorne.	1867—8 Dec. & Jan.	Water supply derived from shallow wells, round which every possible pollution had accumulated. A sudden great rise in the water levels after heavy frost and snow, undoubtedly showed that the wells had become the receptacles for the washings of the filth sodden soil.	The whole village became infected, and quite a panic ensued. Children and women suffered most. [The whole village was in a most degraded and unwholesome condition.]	300	41
18. TIDESWELL (Derby). Population, 1,905.	1876. Mch.—May.	Suction of infected air from closets into main of water service, which was occasionally intermittent.	Of the 16 cases, 10, including all the earlier ones, took water from this main. The pollution of the air from the communication of sink-stone-pipes with an arched-in sewer, doubtless contributed to the epidemic.	16	7
19. WICKEN BENANT (Essex). Dr. Buchanan.	1869. July—Dec.	Pollution of the parish well with typhoid germs by percolation from brook, into which infected fæces had found their way.	Epidemic almost exclusively ($\frac{43}{45}$) attacked persons using the parish well, or, occasionally, the brook.	45	4

with regard to different diseases, both as to the amount and value of evidence. There are some people who deny that even considerable organic or mineral impurity can be proved to produce any bad effect; whilst others have believed that some mineral ingredients, such as calcium carbonate, are useful. On these points I cannot now dwell, and I must, therefore, pass over any examination of the diseases, such as diarrhœa, goitre, malarious fevers, and dyspepsia, which may be induced by water, impure at its source, or highly charged with mineral or other impurities. I proceed at once to consider the dangers—and they are immense—of

(*b.*) *Water Polluted with the Specific Infection of some Particular Disease.*—Two diseases, closely correlated, stand out in very bold relief in this connexion. I refer, of course, to cholera and typhoid fever. It is to be hoped that the system of medical inspection, now in force at all our ports, will suffice for the future to nip in the bud any stray cases of the former disease that may reach our shores. In the epidemics which occurred from cholera in this country in 1849, 1854, and 1866, its spread, by means of water polluted with its specific infection, was painfully and convincingly proved by a greater mass of evidence than had ever been previously collected. With regard to any other disease, I do not propose on this occasion to attempt to give any illustrations of the spread of cholera by water. The Broad-street pump outbreak, investigated by Dr. Snow, to whom we owe the first proofs of the spread of cholera by water, is historical. There are many other instances recorded on pages 153 to 161 of the Sixth Report of the Rivers Pollution Commission, but as the time is short, and cholera is an exotic disease which we have only occasionally to fear, I hurry on to an examination of the spread of typhoid fever by water. Here there is of evidence an overwhelming *embarras de richesses*. Epidemics by the score, nay by the hundred, might be cited in which the first cause has been the pollution of the water drank by the persons affected. In fact, it has been one of our most familiar experiences, one which will be found exemplified in every volume of every medical journal, that excremental fouling of wells is, in this respect, among the worst dangers which can threaten the health of a community; and other common water supplies, as distributed by companies and local Boards, are equally capable of spreading the infection. In the admirable Fifth Report of Mr. Simon, an abstract is given of the history of no less than 146 epidemics of typhoid fever investigated by his department during the four years 1870-3. In all these cases great excremental pollution of air or water—generally of both—was found. Since then several very remarkable outbreaks of the same kind have been investigated by the Local Government Board with the same result.

These reports may be broadly divided into three sections, those showing the impurity to be imparted (1.) at the source; (2.) in transit from the source to the reservoirs; (3.) when stored in tanks or cisterns. It will be obvious that the two last dangers concern town water only, *i.e.*, that delivered in pipes to the several houses. The first mentioned source of impurity is, therefore, the one which we most commonly find as concerned in rural districts with the spread of typhoid fever. In country places wells are not uncommonly found in close juxtaposition with privies, and soakage from the latter to the former inevitably ensues. The water may perhaps be drunk for a long time without any grave danger to health, but as soon as the infection of typhoid fever gets into the well most serious results follow. Thus, at Hawkesbury Upton, which is situated upon fissured oolite, the sewage is discharged into the fissures, Into the same fissured rock are sunk the wells, and when a case of enteric fever occurred at the top of the village the disease spread through the whole village through the medium of the privies and wells. The use of brook water again, when infected with the contagium of enteric fever, has been proved in innumerable instances to have been the cause of epidemics of the disease. Perhaps one of the most convincing cases of this sort occurred at the orphan asylum founded at Bristol by the philanthropic Mr. Müller.[*] An extensive outbreak (something like 500 cases occurred) was shown by Mr. Davies, the Medical Officer of Health for the City, to have been caused by the drinking, by the children, whilst out for a walk, of water from a stream in a picturesque dingle, but polluted by sewage from a neighbouring village, in which enteric fever was prevalent.[†]

A very remarkable outbreak, of a totally different kind, has only just occurred near London, in the Caterham Valley. The water supplied by the local water company is above suspicion as regards contamination from cesspools; but some time in January, a man who was suffering from a mild attack of typhoid fever was employed in some work beneath the surface in connection with one of the company's wells sunk in the chalk. There is no doubt whatever that he imparted the specific contamination of typhoid to the water in the well, for, after the usual period of the incubation of the disease, more than 300 cases broke out amongst persons using the company's water. Unhappily, several deaths have resulted from this distressing occurrence, but the company have taken every precaution to prevent a similar accident occurring in future.[‡]

Of the second sort of contamination—that received in the transist of the water from the source to the reservoir—no better example could be given than the epidemic at Over Darwen in 1874.[§] This outbreak, which was minutely investigated by Dr. Stevens, of the Local Government Board, and which attacked 1,500 persons, killing 85, was shown to have been occasioned in the following way. In September, a young lady died of enteric fever, at a house situated close by the "sough," by which the water supplying Over Darwin is conveyed into the service reservoir. Examination showed that a drain carrying away the sewage from the house, passed near this "sough," and had gained access to its interior through faults in its imperfectly secured joints. There was no sort of doubt that this was the true explanation of the epidemic.

Town water, though it is usually absolved from gross impurities at its source as rural water is, has many dangers of its own. In fact, the chance of ubstances getting into the water of tanks and isterns is very great. Leakages from ditches, assage of foul air through pipes, or direct absorption of air by an uncovered surface of water inroduce impurities into cisterns. A danger which eems capable of wide operation has been seen to rise when water-closets receive their flushing ervice from the mains of a so-called "constant" upply. This danger is that during times of ntermission, if there are not service boxes or isterns between the closet-taps and the mains, effluvia and even in some cases fluid filth will be (so to speak) sucked into water-pipes. It is to Dr. Bloxall that we owe the discovery of the connexion of this condition with outbreaks of enteric fever. Subsequent investigations by Dr. Buchanan at Caius College, Cambridge, and on a much larger scale at Croydon, in the year 1875, fully confirm this theory. Dr. Thorne has also reported an outbreaks at Lewes and Tidewell, which lead to the same conclusion.

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[*] *Sanitary Record*, vol. III., p. 86.

[†] *Ibid.*

[‡] *Ibid.*, vol. x.

[§] *Ibid.*, vol. II.

METHODS OF SEWAGE, &c.

NOTES OF PROGRESS WITH SEWAGE SINCE THE FIRST CONGRESS OF THE SOCIETY OF ARTS IN 1876, SUBMITTED TO THE FOURTH CONGRESS IN 1879.

By Sir Henry Cole, K.C.B.

1. The Rt. Hon. James Stansfeld, late President of the Local Government Board, has delivered three addresses at the Conferences on Sewage, which have taken place in this room. These addresses, for the soundness of their doctrine and advice and useful suggestions, might well be repeated on this occasion. They are silently, although too slowly, bearing fruit. But there was one suggestion of paramount importance, and not difficult to carry out, to which I would call attention, in the hope that we may see it accomplished before our next Conference.

2. Mr. Stansfeld suggested that there should be an *Inquiry Department*, where any one could go to put any question on Sewage in the interest of the town he represented, and get the best possible answer, and he said, if the Local Government Board did not institute it, the Society of Arts might. But neither Government nor Society have as yet acted on this sound advice given in 1876.

3. The public ignorance on sewage subjects is still universal and deep, but is becoming less so. In London, the majority of houses are not properly connected with the main sewers, although four millions have been spent on the sewers, and our vestry masters cannot show to a proposing tenant what the state of the connexion is in the majority of houses. Houses when connected are generally but a ventilating shaft for sewer gas everywhere. I have lived in four furnished houses, during my provincial inquiries, in the last two years, and every house was a ventilating shaft for sewer gas. But the difference between London and the provinces is, that Birmingham and Manchester, with admirable promptness, compel the landlord to expel the demon of typhoid fever, whilst London allows him to remain.

4. I proceed to give a few important instances of how little progress has been made since the Conferences began. Our chairman said, in 1876, that the Congresses were intended to take stock year after year of the experience of the country. I propose to take a little stock of how the country now stands, and notice a very few marked examples.

5. In our principal City, with its four millions of people, the Thames in the metropolis remains as foul as ever. When Parliament could bear it no longer, lime, unlimited in quantity, could be used to purify the sewage at the West-end. The Metropolitan Board of Works affects to say that Sewage at the East-end does not require purification. The Thames Conservancy Board, it is said, are taking slow legal measures to correct the views of the Metropolitan Board of Works, but the Board makes no sign of doing anything; whilst it flinches from asking the metropolitan ratepayers for even a penny a year for effectually getting rid of the impurities. In the upper part of the Thames, the results of the different plans adopted at Oxford, Reading, and Windsor, are not sufficiently ascertained to be discussed, but doubts are expressed of their success. In the Lower Thames Valley district the attempt to place a sewage farm between Hampton-court and Claremont has been discouraged by the House of Commons, and the Bill not even allowed to be discussed.

6. In large provincial towns, passiveness only appears to reign. Birmingham (with its 360,000 population) goes on with precipitation and digging the sludge into the land, and it makes the best

effluent it can; but it may be doubled if it comes up to an authoritative standard of purity. It is tolerated by Lord Norton, however. Manchester has plans for a federation of places in the immediate suburbs, but it has no settled scheme of purification. Until Oldham and other great towns, now polluting the rivers which flow through Manchester, act, it would be useless for Manchester to attempt a purification. In the meantime a little place, Withington, with 20,000 inhabitants, has been permitted to borrow money to forward the commencement of a Sewage farm in the midst of a populous neighbourhood! Salford, with 140,000 people, has done nothing. Leeds, with 300,000 people, goes on accumulating its sludge by hundreds of tons. Glasgow, with nearly half a million of people, proposes to use precipitation, and take the sludge down the Clyde to the sea. Leicester cannot decide what to do with its sludge. Facts connected with 100 places, having about three millions of population, have been collected and are appended to this paper. It is typical of the state of public paralysis.

7. Only eleven places, out of about 70 addressed by the Society of Arts, have sent in returns relating to Irrigation for the use of this Congress, and they give no important information. Wolverhampton (75,000 population) is said to have found out that it is quite possible to overdose the land with dirty sewage, and is looking out for more land to give rest to its present farms.

8. Two or three conclusions respecting farming by sewage now seem to be admitted. 1. That the storm water must be kept out of the sewers; 2. That precipitation must take place before the sewage flows on the land; 3. That filtration of some kind after precipitation is most desirable; 4. Another conclusion is, that towns cannot make a profit out of water-carried sewage, a fallacy which haunts old-fashioned minds, especially in the Metropolitan Board. I believe Croydon and Stoke-on-Trent are likely to show new combinations of treatments, which may be useful.

9. Compulsory federation of small places under a united local management is a subject which, I think, is ripe for the Local Government Board at once to insist on. The Duke of Sutherland, who, among great landlords, has taken a prominent and patriotic part in overcoming the sewage difficulties, addressed a letter, which I am permitted to quote, to the President of the Local Government Board. It is as follows:—

Letter sent by the Duke of Sutherland to the Right Hon. G. Sclater-Booth, President of the Local Government Board.

28th January, 1879.

SIR,—The two printed documents which accompany this letter relate to the purification and conservancy of rivers in Lancashire, and have come before me. Whilst I feel myself justified, on public grounds, in sending them to you for the consideration of the Local Government Board, I do so all the more, because I have personal evidence of the delays and bad results of the want of union and co-operation in the various towns of the Potteries in dealing with the pollution of the River Trent by sewage, which passes through my property.

Places in Lancashire, as in other counties, have hesitated to comply with the law prohibiting the pollution of rivers, partly because they shrunk from the necessary expenditure, and partly because the purification of one or two places on a river was of little use, unless along the whole course of the river. A glance at the sketch map of the Irkwell basin (published in the report of the Rivers Pollution Commissioners) forcibly illustrates this fact. For example, the unpurified sewage of Oldham finds its way through the Irk and Medlock to Manchester. The sewage of Bolton, Bury, and of Rochdale, &c., all descend, by the Irwell, through Salford and Manchester. Unless each of these purifies its own sewage, the law cannot equitably be enforced on Manchester and Salford. This seems a special case where the direct intervention of the Local Government Board, to act simultaneously, is called for on every account; and I venture to express my conviction to you, of the urgent public policy of advising Oldham to act at once in purifying the sewage of its own locality, and bringing into federation the small adjacent places. It would seem desirable that a limited period should be fixed for accomplishing the work. If this advice were given by the Local Government Board, I believe Manchester and Salford would then proceed with their own duty of purification, and a useful example to all places in Lancashire and Yorkshire would be set.

Having regard to the great magnitude of the work, and my interest in its national importance, I hope you will not think I am carried too far if I ask you to consider the expediency of constituting some organisation in Lancashire, which, in friendly communication with all places, might aid in inducing Lancashire, in its respective catchment basins, to unite in laying out, without further delay, the several necessary schemes for purifying the rivers of the sewage.

By adopting the principles of federation, I am convinced that a great benefit would be conferred on the several millions of the people congregated in the manufacturing places of the North of England, which constitute a large proportion of the country; whilst, without such stimulus, experience has shown that the work may continue undone for years. Conservancy over rivers, which the Committee of the House of Lords recommended in 1877, seems inevitable in the progress of sanitary improvement, and some preliminary inquiries and action would appear to be a useful preparation for introducing that necessary conservancy of rivers.* I am, &c.,

SUTHERLAND.

The answer of the Board was favourable, but it stopped short of adopting compulsory action.

Local Government Board, Whitehall, S.W
4th March, 1879.

MY LORD DUKE,—I am directed by the Local Government Board to state that they have considered the representations contained in your Grace's letter of the 28th of January last, and they wish to observe that they are always ready to give attention to any application, which may be made to them for the formation of any large united district for purposes of sewage disposal, under Section 279 of the Public Health Act, 1875. Moreover, they are also ready at all times to render any assistance in their power to local authorities who wish to combine for these purposes, under Section 285 of the Act. Some combinations have already been formed under both of these enactments, and the Board have now before them some cases in which it is proposed that like combinations should be formed under one or other of the sections in question.

At the same time the Board's experience leads them to believe that, generally speaking, it is desirable for them to wait until their assistance is sought, by one or more of the sanitary authorities proposing to form a combination, before they interfere in the matter; and it must be borne in mind that the Board have no power o compel a combination under Section 285, and that hey can only proceed under Section 279 upon the application of one of the sanitary authorities interested.

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* A Bill has passed the House of Lords this Session.

The Board have not at present received any such application with respect to any of the places to which your Grace refers, but with regard to some of these places, they have before them matters which involve he question of sewage purification.

In dealing with these matters, the Board will not fail o give consideration to the views expressed by your Grace as to the desirability of a combination of authorities being formed to deal with the disposal of the ewage.

I have the honour to be, my Lord Duke,
Your Grace's obedient servant,
(Signed) John Lambert, Secretary.

To His Grace the Duke of Sutherland, K.G.

10. An opinion has been expressed by civil ngineers of knowledge and experience, that sanitary science has been retarded by the antiquated prejudices of the inspectors of the Local Government Board in favour of Irrigation. A late President of the Institute of Civil Engineers once said o me:—"The simple result of the utilisation of Sewage by Irrigation is the production of a penny cabbage at the cost of sixpence, and a pestilential neighbourhood besides."

11. The risks of sewage irrigation of the Local Government Board were exposed in the Report of 1876, when the following cautions were issued:—

> "Land irrigation is not practicable in all cases, and therefore other modes of dealing with Sewage must be allowed.—(p. xiii.)
>
> "The continuous application of town sewage to all soils is by no means an unalloyed benefit, as in some cases and seasons, and especially upon dry land, it may be rather injurious than otherwise. Very few crops are actually benefited by the direct application of sewage upon a stiff and retentive soil; indeed, Italian rye grass, cabbage, and mangold wurzel seem to be the only farm crops that persistently flourish upon any soils, heavy or light, under continual doses of town sewage. . . . The cultivation of sewaged land, for instance, requires more than double the amount of manual labour which is usually employed upon arable land, and more horses must be kept than upon an ordinary farm. . . . . To properly stock and work a sewage farm, upon which the main produce is consumed, quite five times the usual amount of money will be needed. One of the greatest difficulties is to keep the sewaged land clean."
>
> "We have been also assured by a gentleman of vast experience that the long-continued application of sewage to the same land fails to produce the like beneficial effect as when it was first used."
>
> "Most sewage farms are at present under the control of ever-changing Town Councils and Local Boards, whose members must, as a rule, be ignorant of practical agriculture." (p. xxxvi). "Disappointment has therefore been expressed at the poor financial results of sewage farms."

Notwithstanding the official publication of these views, some Inspectors of the Board continued to insist upon the acquisition of land, in unnecessary quantities, as the first condition of recommending a loan. When in Manchester last year, two cases were brought to my notice, and I was impelled to call the attention of the Local Government Board to reports, published in the Manchester newspapers, of the observations of inspectors made at local inquiries on the quantity of land required for purification of sewage. I received an official answer, dated 6th February, 1879, stating, "that the President can only say that the inspectors are instructed not to express publicly any opinion upon the proposals into which they have to inquire, except in those cases when the views of the Board have been distinctly ascertained on the subject, and the Board themselves are always very careful to abstain from advising local authorities as to the particular scheme which they ought to adopt. In fact, when the Board are applied to for advice as to the sewage of a district, they invariably recommend the local authority to call in and consult some competent engineer, and point out to them that it is only when plans have been prepared, and a loan is required, that the Board will be in a position to consider the matter. Of course, when application is made to the Board to sanction loans for works, it is requisite that they should take all necessary precautions to satisfy themselves that the works will be effectual; but so far from discouraging scientific progress, they are only too glad to have brought under their notice any scheme which can be reasonably relied upon as combining economy with efficiency in dealing with the difficult question of sewage disposal."

12. Nothing can be more satisfactory than this declaration of principles, which, I believe, will prove of the highest value to the progress of sanitary science, and I rejoice that I have the opportunity of thanking Mr. Sclater-Booth, the President of the Local Government Board, for it. I am sure it will be most acceptable and encouraging to the sanitary engineers throughout the country.

13. In the present state of public opinion and knowledge, I submit that strong compulsory legislation, to deal with the science of sanitation, is hardly possible, and not desirable. In sanitary, as in other subjects, Government in this country must follow, and not lead, public opinion; and it can never be dogmatic in science. But as the public mind becomes made up for action, it seems that the Government should itself act promptly. Federation of small places, with central local action, may be insisted on, and compulsory prohibition against polluting the Thames seems to me a case where Government may say at once, "This must be no longer."

APPENDIX A.

Confederation of Places in Catchment Basins of Rivers to Promote the Economical Purification of Sewage.

Places on the Rivers, Streams, and Watercourses in the Irwell, Mersey, Ribble, and Calder Catchment Basins, having 5,000 inhabitants and upwards, and the present state of their sewage.

The facts stated are compiled from Lord Rosebery's Parliamentary Return, 1876: Local Government Directory, 1877, and various Sanitary Reports of the Society of Arts, &c., and have been submitted for correction to the several local authorities.

Irwell Basin.

Astley Bridge.—Population, 6,000; rateable value, £23,174; Astley Brook into Croal. No return.

Audenshaw.—Population, 6,000; rateable value, £16,500; Tame. Some sewage scheme authorised by Local Government Board in process of execution.

Bacup.—Population, 29,000; rateable value, £83,017; Irwell. No return.

Barton Eccles.—Population, 19,000; rateable value, £70,000; Irwell. Nothing done.

Bolton. — Population, 105,000; rateable value, £296,646; Croal, Tonge, and Irwell. Bolton has a lime precipitation scheme, but has difficulty in disposing of the sludge.

Bradford. — Population, 14,000; rateable value, £27,643; Medlock. No return.

Bury.—Population, 52,000; rateable value, £210,063; Roach and Irwell. Nothing done. Drainage plans preparing by Mr. Cartwright, Borough Surveyor.

Castleton by Rochdale.—Population, 4,000; rateable value, £23,000; Roach. Nothing done. Mr. Farrar, C.E., is preparing plans.

Chadderton.—Population, 14,200; rateable value, £60,001; Irk. Nothing done.

Crompton (near Oldham.)—Population, 7,300; rateable value, £29,745; Roach, Irk, and Beal. Nothing done. Mr. Farrar, C.E., is preparing plans.

Crumpsall. — Population, 5,340; rateable value, £23,751; Irk. Nothing done.

Droylsden. — Population, 6,678; rateable value, £21,374; Medlock. Nothing done. This district has been in correspondence with the Manchester Corporation, and may, with other adjoining districts, be included in their scheme.

Failsworth. — Population, 6,800; rateable value, £29,264; Moston Brook into Irk. Nothing done as yet.

Farnworth.—Population, 22,000; rateable value, £56,000; Croal. No return.

Gorton.—Population, 31,000; rateable value, £89,798; Irwell and Mersey. Nothing done.

Halliwell.—Population, 10,000: rateable value, £40,540; Astley Brook into Croal. Nothing done. Incorporated.

Haslingden.—Population, 13,000; rateable value, £40,020; Irwell. Nothing done. Mr. Farrar, C.E., has prepared plans. Works in progress.

Heywood. — Population, 23,000; rateable value, £97,903; now drained under Mr. Farrar, C.E.

Kearsley. — Population, 5,950; rateable value, £28,548; Irwell. Nothing done.

Littleborough.—Population, 8,500; rateable value, £31,300; Roach. Nothing done. Drainage begun under Mr. Shuttleworth, Local Board Surveyor.

Little Lever.—Population, 4,204; rateable value, £18,218; Irwell. Mr. Garrar, C.E., has prepared plans.

Manchester.—Population, 351,180; rateable value, £2,125,759. Plans prepared by Mr. Bateman and Mr. Lynde. They inclue a treatment of the sewage on north side of Harpurhey (Irk, population,); Newton (Shootersbrook, population, 22,000). On south side, of Rusholme (Irwell, population, 10,670). Moss Side (Irwell, population, 12,500), Levenshulme (population, 2,500); Withington (Irwell, population,); Stretford (Irwell, population, 19,000); and Barton-on-Irwell (population, 19,000). On the west side, Droylsden (Medlock, population, 6,678); Openshaw (Gorton Brook, population, 13,500): Gorton (Irwell, population, 31,000).

Middleton. — Population, 14,580; rateable value, £36,461; Irk. Nothing done.

Milnrow. — Population, 6,700; rateable value, £19,751; Beal. Nothing done.

Moss-side. — Population, 12,500; rateable value, £63,151; Irwell. Nothing done.

Newton Heath. — Population, 25,000; rateable value, £86,552; Medlock.

Oldham. — Population, 100,000; rateable value, £393,579; Irk and Medlock. Nothing done.

Prestwich. — Population, 6,820; rateable value, £32,084; Irwell. Nothing done.

Radcliffe. — Population, 15,000; rateable value £71,402; Irwell. Drainage commenced under Mr Farrar, C.E. Drainage on hand now.

Rawtenstall.—Population, 18,000; rateable value. £37,174; Irwell. Nothing done.

Rochdale. — Population, 68,650; rateable value. £279,623; Roach and Spodden. Nothing done. Drainage plans preparing by Mr. Hewson, Borough Surveyor.

Royton.—Population, 8,000; rateable value, £27,63[illegible]. Irk. Nothing done.

Rusholme. — Population, 10,670; rateable value. £72,353; Irwell and Mersey. Nothing done.

Salford. — Population, 138,890; rateable value £749,632; Irwell.

Stretford.—Population, 19,000; rateable value, £108,000; Irwell. Nothing done. A small settling tank is fixed on the banks of the Mersey for the village portion of sewage.

Swinton and Pendlebury. — Population, 20,000. rateable value, £67,907; Irwell. Nothing done. Messrs. Brookbank, Wilson, and Mulliner are preparing plans.

Whitefield.—Population, 9,800; rateable value. £39,412; Irwell. Drainage begun under Mr. Farrar C.E.

Whitworth.—Population, 11,000; rateable value, £38,218; Spodden. Nothing done. (48 places.)

Mersey Basin.

Ashton in Makerfield.—Population, 9,000; rateable value, £47,000; Down Brook and Millingford Brook tributary of Mersey. The Ashton Local Board have carried out an irrigation scheme.

Ashton on Mersey.—Population, 10,000; Mersey. Drainage commenced under Mr. Newton, C.E.

Ashton-under-Lyne.—Population, 31,980; rateable value, £101,437; Tame polluted and flows into Mersey

Atherton. — Population, 10,200; rateable value, £40,600; various brooks into Mersey. Main sewers and Lime Precipitation Works on the point of completion.

Birkenhead.—Population, 55,000; rateable value £232,312; Mersey. Nothing done.

Bootle-cum Linacre.—Population, 24,500; rateable value, £116,102; Mersey. Nothing done.

Cheadle. — Population, 6,000; rateable value. £40,000; Micker Brook and Mersey. Nothing done Plans prepared by R. Vawser, C.E.

Denton.—Population, 6,000; rateable value, £19,6[illegible]. Mersey. Nothing done.

Dukinfield.—Population, 16,000; rateable value, £54,378; Tame polluted into Mersey. Mr. Cartwright, C.E., has prepared plans for intercepting sewers.

Garston. — Population, 8,500: rateable value £55,440; Mersey. Nothing done.

Haydock. — Population, 5,280; rateable value £18,763; Sankey Brook into Mersey. Nothing done

Heaton Norris.—Population, 5,500; rateable value £26,995; Mersey. Drainage commenced under Mr. H. Lynde, C.E. Main drainage estimated to cost about £15,000. No system of purification as yet adopted

Hindley.—Population, 10,620; rateable value £54,190; Bosdane Brook into Mersey. Nothing done

Hurst.—Population, 5,650; rateable value, £15,[illegible] Hurst Brook pollutes the Tame. Nothing done.

Hyde.—Population, 14,223; rateable value, £54,000 Tame. Nothing done. Plans prepared by R. Vawser C.E.

Leigh.—Population, 19,700; rateable value, £61,[illegible] Glazebrook tributary of Mersey. Nothing done.

Liverpool.—Population, 521,500; rateable value £3,000,395; Mersey. Nothing done.

Macclesfield.—Population, 35,671; rateable value £78,079; Bollin into Mersey. Nothing done.

Mossley.—Population, 15,000; rateable value £86,000; Tame polluted into Mersey. Nothing done.

Newton in Makerfield.—Population, 9,000; rate able value, £38,000; Newton Brook, Sankey Brook into Mersey. Nothing done.

Prescot.—Population, 5,990; rateable value, £11,682; Prescot Brook by Sankey Brook into Mersey.

Runcorn.—Population, 14,000; rateable value, £39,613; Mersey. Nothing done.

St. Helens.—Population, 50,000; rateable value, £188,795; Sankey Brook into Mersey. Nothing done.

Sale.—Population, 5,573; rateable value, £44,162; Mersey. No system of treatment.

Stalybridge.—Population, 21,040; rateable value, £70,000; Tame polluted into Mersey. Nothing done.

Stockport.—Population, 53,001; rateable value, £161,687; Mersey. No system of treatment.

Toxteth-park.—Population, 7,000; rateable value, £60,281; Mersey. Nothing done.

Tranmere.—Population, 17,478; rateable value, £66,972; Mersey. Nothing done.

Tyldesley.—Population, 8650; rateable value, £40,132; Hindsford Brook into Mersey. Nothing done. Has an irrigation scheme prepared. Plans prepared by R. Vawser, C.E. Application has been made for sanction to borrow £30,000, for the purchase of land for sewage irrigation, and for main drains.

Wallasey.—Population, 14,819; rateable value, £95,599; Mersey. Nothing done.

Warrington.—Population, 40,000; rateable value, £125,228; Mersey polluted. Nothing done.

Waterloo with Seaforth.—Population, 7,000; rateable value, £47,124; Mersey. Nothing done.

Wavertree.—Population, 8,000; rateable value, £73,887; Mersey. Nothing done.

West Derby.—Population, 31,400; rateable value, £166,758; Mersey and Alt. Has a sewage farm to which the sewage of the greater part of the district is taken. The sewage of a small part only of the district, goes into the Mersey through the sewers of Liverpool.

Westhoughton.—Population, 8,220; rateable value, £31,176; Brooks into Mersey. Nothing done.

Widnes.—Population, 20,000; rateable value, £86,156; Mersey polluted. Nothing done. (37 places.)

Ribble and Calder Basin with Pendle Water, &c.

Accrington.—Population, 34,000; rateable value, £80,241; Hyndburn River and Accrington Brook. Sewage water disinfected with McDougall's fluid.

Blackburn.—Population, 90,000; rateable value, £247,104; Darwen tributary of the Ribble.

Burnley.—Population, 49,000; rateable value, £112,185; Brun, Calder, and Pendle. Purified by Scott's process.

Chorley.—Population, 18,000; rateable value, £56,352; Yarrow into Douglas and Ribble. Irrigation.

Clayton-le-moors.—Population, 6,500; rateable value, £15,928: Hyndburn. Nothing done.

Clitheroe.—Population, 8,217; rateable value, £26,136; Wilkin Brook tributary of the Ribble. Nothing done.

Great Harwood.—Population, 5,500; rateable value, £14,000; Hyndburn. Nothing done.

Over Darwen.—Population, 25,000; rateable value, £66,778; Darwen.

Padiham and Hapton.—Population, 9,000; rateable value, £17,200; Calder. Nothing done.

Preston.—Population, 85,428; rateable value, £247,110; Ribble. Nothing done.

Todmorden.—Population, 25,000; rateable value, £64,475; Calder polluted. Nothing done.

Wigan.—Population, 42,000; rateable value, £114,064; Douglas. Nothing done. [13 places. Total, 98 places.]

Note.—The numbers of the population and the amount of the rateable value, taken from the Local Government Directory of 1877, should be considered only as approximate. In numerous cases the population given in the Local Government Directory differs from Lord Rosebery's return.

THE THAMES AND ITS TRIBUTARIES.

By C. N. Cresswell, Inner Temple.

At the commencement of the present century, the Thames was a pure and wholesome river. Now, throughout a great part of its course, it is the common sewer of Middlesex and Surrey. The Thames has many tributaries; either natural streams, as the Mole, the Crane, and the Brent, converted into open sewers by a process of gradual contamination, or artificial feeders directly conveying the sewage of populous towns into the river bed. This is the practical outcome of sanitary efforts in the Thames Valley during the past 30 years, the history of which period is a tale of doing and undoing, of official meddling and local muddling; of misdirected zeal on the one hand, inert bewilderment on the other. Heretofore the public health had been no concern of Government, but the ravages of cholera in 1847, and the abnormal increase of disease in the centres of population, arrested the attention of the Legislature. In 1848 the era of tentative legislation began, and the Act was passed "for improving the sanitary condition of towns." The metropolis and its suburbs were excluded from this Act, for divers occult reasons not altogether intelligible to ordinary minds. The alleged ground was, that the sanitary condition of the metropolis had, for a period, as far back as the reign of Henry VIII., been regulated by Commissioners of Sewers, the powers and jurisdiction of which were extended and consolidated by another Act in the same year.

In 1850, by Order in Council in pursuance of this Act, Richmond was included within the jurisdiction of the Metropolitan Commissioners, and a local inquiry was held by Mr. Donaldson for the purpose of investigating the best means of improving its sanitary condition. He advised, and designed a plan, for carrying the sewage to the old Deer-park belonging to the Crown. The Crown objected, and the Commissioners thereupon resolved to take the whole sewage direct into the Thames. The inhabitants, alarmed by the prospect of river pollution, protested against the profanation, but they protested in vain; the fiat had gone forth, and the sewage soon flowed by two outfalls into the river, one above, and the other below the old bridge.

A system of sewers was constructed at a cost of more than £20,000, and the Commissioners of the period approved the work, persuaded that they had taken an exemplary step in a right direction. There were stringent provisions in the Act of 1848, for perfecting the drainage of towns; cesspools and middens alike disappeared; water-closets became the order of the day, and an augmented volume of intercepted sulliage went on its silent way into the bosom of Father Thames. Nobody seemed to anticipate pollution in that day; "organisms and fungoid growths" were in the womb of the future, dimly descried, perchance, by croakers and crotchet-mongers, but as yet unrealised in the world's philosophy. The town of Richmond having been thus well provided, the good example was not lost upon the neighbouring towns and villages. Twickenham, Isleworth, Kew, and Brentford followed suit with commendable alacrity, and the gas works of the last-mentioned town gratuitously diversified the general current of contamination.

Other towns upon the Thames, outside the jurisdiction of the Commissioners, obeyed the common impulse; until, in 1855, flounders, gudgeon, and other delicate fish refused to face the opposing filth, and the occupation of many a fisherman in the middle reaches was gone. At the same time, the state of the river at low tide forbade the recreation of either bathing or boating to the inhabitants below the village of Twickenham.

In 1861, a Royal Commission reported that the pollution of the rivers of the country had "become a national evil," and, in 1866, Parliament, alarmed by the consequences of its own handiwork, passed the "Thames Navigation Acts," for the purpose of restraining the flow of crude sewage and other refuse into the Thames, or any watercourse within three miles of its channel.

The effect of this change of front upon the local authorities, who were not left long in doubt as to the object of the Acts or the intentions of the Conservators, was general consternation. There were memorials to the Secretary of State, and Committees of the House of Lords, as to the exceptional situation of these riverside towns, where the value of land was high, and the adjacent Crown properties shut them in on either side. Nevertheless, notices were served by the Conservancy as soon as their Act was passed, and the sewage, which the Commissioners of 1850 had carried into the river, could be permitted to pollute it no longer.

The notice of 1867 produced some interesting correspondence, nothing more! It was renewed in 1869, when Richmond had recourse to Parliament. A reprieve of two more years was given, and the authorities again proposed to dispose of the sewage by means of irrigation on land near Maldon. This failed. Thereupon, precipitation was suggested, upon a site in the old Deer-park. The Crown authorities again objected, more peremptorily than before. Then ensued a series of Local Government inquiries, culminating, at length, in a Provisional Order in the year 1872, which was afterwards abandoned as an impracticable abortion. There were a further attempt at irrigation near Hanworth, and, finally, both Kingston and Richmond were advised to adopt precipitation on Ham fields. But all in vain! Mr. Rawlinson decided against Kingston, although the spot selected was within the parish, while Mr. Hawksley's recommendation of the same site for Richmond provoked a still greater storm of opposition from the local proprietors, on the ground that it was without the district of that sanitary authority.

Driven to bay, Richmond appealed to the Board of Trade, and the award of Capt. Douglas Galton secured for it a further reprieve of two years. The Conservators, during this interval, directed their attention to the neighbouring towns, and local inquiries, held in quick succession, kept the Thames Valley in a condition of sanitary fermentation.

Two years previously—viz., in 1872—there had been held at Kingston a kind of Sewage Parliament, at which Sir Joseph Bazalgette had expounded his plans for purifying the river, from Windsor to the metropolis, by pumping the sewage backwards to land at Woodham-heath, near Chobham. This congress of representatives, without either legal status or power of cohesion, had no result, and the project of Sir Joseph Bazalgette was never fairly discussed. Another, less ambitious attempt at combination failed, when Kingston broke away from the projected union, and proposed a scheme of chemical precipitation on the banks of the Thames, near the Borough Gasworks, and opposite to Hampton-wick. The inhabitants of that suburban retreat rose at once, marshalled by the Chairman of the Local Board, and defeated the proposed plan of sewage disposal, on the ground that one already existing nuisance (of a gasworks) could not justify the gratuitous imposition of another.

Hampton-wick itself had not escaped the omnivorous attention of the Conservators, who had, in the interval, served notices also upon Heston and Isleworth, Twickenham, Kew, Brentford, and other riverside offenders. Meanwhile, the Public Health Act of 1875 was passed, amid feelings of general dismay and helplessness, and Surbiton came to the front forthwith, with a plan of uniting the adjoining districts in one combination, under the provisions of that Act. Sir Joseph Bazalgette had projected another scheme for carrying the sewage of the proposed district downwards into the River Thames at Sea-Reach, in combination with the West Kent drainage system, which had just received the sanction of Parliament.

This is known as the "heroic scheme," and after long consideration, and more than one local inquiry, was rejected by Col. Ponsonby Cox, R.E., as a conception which, although practicable from an engineer's point of view, was beyond the needs and limited resources of the Thames Valley district.

To his famous report of January 11th, 1866, he appended certain suggestions as to the best "practical mode of dealing with the sewage" of places situate below Teddington-lock, viz., by "precipitation processes efficiently worked;" and the official promulgation, in the March following, of these opportune suggestions, excited a new sensation, together with a sense of real relief, among the bewildered local authorities.

In October, of the same year, a conference of delegates from each local authority was held, under the presidency of Col. Cox, R.E., himself, at Westminster, to consider the question of united action, within the provisions of the Act. However, Twickenham and Brentford held proudly aloof from this conference, and it was left for another local inquiry at Kingston, in February, 1877, to determine the limits of the proposed combination. In that year, all the districts named in the application of Hampton-wick, were combined by provisional order, save Heston, Isleworth, and Brentford, and a few other places, which were reserved for after consideration. Twickenham, in spite of vehement opposition, had been scheduled in the proposed combination, but the inhabitants carried their case into the Committee of Parliament; and, after a hard fought contest, made good their contentions, and were finally excluded.

At the end of 1876, Heston and Isleworth, and Brentford, resolved to give effect to the suggestions contained in Colonel Cox's report of that year, and to provide for themselves a system of sewage disposal "by means of precipitation processes efficiently worked," within their own borders.

The projects of both districts were summarily rejected; and the respective local authorities discovered to their cost that the favourable opinion of one Government officer will not secure the assent of another, and that the department in Whitehall does not hold itself bound to the approval of a scheme which has been designed in direct pursuance of the recommendation of its own inspector!

After this disclosure, it is difficult to estimate the exact value or purpose of local inquiries, or even of official inspectors, unless the reports be read in a sense exactly opposite to that which the authors intended.

Discomfited and disheartened, Heston and Isleworth sought refuge in the united fold. Brentford, like the Peri, still sits expectant at the gate of Paradise.

All eyes were now turned to the "United Drainage Board" for the solution of the vexed question, by means of a mature and well-digested scheme of sewage disposal for the whole district.

It came at last, after much pain and long gestation, under the auspices of Col. Haywood and Mr. Peregrine Birch, in the guise of a colossal project for pumping the sewage over 800 acres of land near Moulsey; whether by crude irrigation merely, whether by irrigation and precipitation, or downward intermittent filtration combined, the outside world has never heard.

We assume, of course, that the engineers had considered the exact method of disposal; but these details were never discussed publicly by the Board, and the most eager inquirer failed to extract any definite information as to details, or estimated cost, of the system to be ultimately adopted. Great names were freely used as sponsors for the superior excellence of the selected plan. Nevertheless, the minds of the ratepayers were disquieted within them, although such men as Dr. Frankland, Col. Jones, V.C., Mr. Chalmers Morton, Dr. Tidy, Mr. Hawkesley, "*cum multis aliis*," had been vouched as to the fitness of the site for irrigation, and the Parliamentary Committee certainly revealed no abatement of confidence. One thing was certain—there would be no local inquiry, as prescribed by the Act which created the Board! To Parliament itself, at one bound, they had resolved to go for a special and enabling Act.

It was, at the same time, announced that the process eventually to be adopted was a mere matter of detail to be considered thereafter. This resolve provoked an outburst of widespread alarm and agitation. Every interest, far or near, local or metropolitan, public or private, personal or official, real or sentimental, combined to resist the threatened intrusion; while certain gratuitous clauses in the Bill for closing their intakes at Thames Ditton, brought all the water companies into the field—a solid phalanx armed to the teeth to do battle for their special rights and privileges.

The contest had waxed furious, when a circular from the United Board was issued to the several constituent authorities, calling their attention to the transparent necessity of separating rainfall from sewage throughout the district to be benefited by the project. We doubt not that the engineers had well considered this indispensable condition of sewage disposal. It is clear that the Board, in its deliberative capacity, had never discussed it. Certainly the constituent authorities had not; and when Richmond and Kingston received the circular for consideration, they flatly refused to give any opinion, or bind themselves beforehand at that stage of the question.

The prospect of having to construct yet another system of sewerage in their much belaboured streets and byeways alarmed the ratepayers of these two towns, and their zeal for the new project visibly abated.

The less populous districts, yet unsewered, easily assented to the proposal; but there were heart burnings abroad, and smothered defection within, and whilst the agitation was at red heat, the House of Commons extinguished the conflict and strangled the Bill upon its second reading. The result has been received with unruffled equanimity by the ratepayers, who await with patience the next scene in a strange eventful history.

You will find its parellel in almost every watershed of the Kingdom. Everybody indeed everywhere is bent upon ridding himself of sewage, and removing the nuisance from his own doors; but nobody thinks, or cares to think, what becomes of the volume of sewage, providing that it be removed beyond his borders.

The dwellers on the banks of the Thames know full well what has become of it. Borne on the tide in uniform oscillations, the filth flows on for ever, even into metropolitan water below Battersea, under the very noses of those who fondly thought to have rid themselves once for all of the nuisance by the main drainage system of the metropolis.

This colossal work, with its pumps and culverts and all the massive grandeur of the Thames Embankments on either shore, is an achievement worthy of its author. Nevertheless, when regarded from that point of view which will find most favour in this Conference, the whole scheme of interception has stopped short of its just fulfilment, and in regard of wasted wealth, and neglected opportunity, has become a national humiliation.

It is cheaper to waste than to utilise it, argue the professors in paradoxical fashion. It is an unworthy excuse; and only another mode of saying "We have not yet found the right method, and there is not sufficient public spirit to take the trouble of searching for it."

Twenty years ago, Cubitt, twice Lord Mayor, declared that the system of sewage interception, combined with the pumps of the water companies, would effect a diversion of the River Thames to the extent of one-fourth of its average volume above Teddington-lock. It is, indeed, far more. That volume, supplemented by the rainfall of the metropolitan area, and polluted by the excreta and ablution of millions of men and animals, is poured daily into the river! 120,000,000 gallons of diluted filth in the immediate vicinity of the populous suburb at Woolwich!

The condition of the river below Barking-creek in the heat of a summer's morning, at mid ebb, beggars all description. The mariner, fog-bound and becalmed, as each turn of the screw stirs up the film and slime floating on the surface, can appreciate at his leisure the well-remembered words of the late Mr. Newton, chairman of committee of the Metropolitan Board of Works. "We have got rid of our sewage" (he is reported to have said in Jan. 1873) "and with the sanitary aspect we have nothing to do."

Nobody, in truth, appears to have anything to do with the sanitary aspect of metropolitan drainage. It is true there is the Rivers Pollution Prevention Act of 1876, but as in 1848, so now in 1876, the metropolis is above the law of the land.

There are Conservators of the River also, and their engineers and Captain Calver, report ever and anon; yet the Conservators do absolutely nothing, paralysed, it may be, by the enormity of the transgression, or aghast at "that matchless intrepidity of face" with which the authorities in Spring-gardens avow the deed, and openly seek to justify it. In justice to the Conservators, I may remark that by their Act of 1867, the duty of preserving the purity of the water of the Thames extends downwards to the western boundary of the metropolis, and not farther, in respect of pollution arising from sewage outfalls. Within their own limits, the Metropolitan Board have violated both the letter and spirit of their Acts, the avowed object of which was "the purification of the Thames." Certain is it that, whatever the technical construction of the statutes, the Legislature at that time contemplated, and the public expected, the utilisation, not the total waste, of the sewage of the metropolis.

Meanwhile, the mischief accumulates, and although the Corporation of London has made some sign, and the Secretary of State is invested with power under the Act, upon complaint made, to direct an inquiry, and take proceedings thereon, nothing has been heard of any application by the Conservancy for the intervention of Government.

Shall it be left to the Council of this Society to beard the authors of a sanitary iniquity? They have done much already to win the gratitude of their country, but action in a matter of this magnitude is surely the work of Government rather than of a scientific association. It is our task to investigate facts, and state conclusions for the guidance of others upon whom lies the responsibility of action.

The conclusions already published by the Council, after our first Conference, have been amply confirmed and established by the experience of the past three years.

Sewage irrigation, chemical precipitation, and downward intermittent filtration, each has had its champions and its battlefields, but the truth lies after all in the *juste milieu*, in the adaptation of different methods to different localities, and oftentimes in a happy combination of them all. Within these broad lines lies all "the law and the prophets" of sanitary science as applied to sewage disposal.

Since the date of the Society's report in June, 1876, the fallacies of some, and the panaceas of others, have been alike refuted, and it is only by working on the lines and in the spirit of that report that we can hope to thread our way through a labyrinth of crotchets and misconceptions.

Unsuccessful promoters and local politicians are apt to rail at popular ignorance or apathy, but the fault lies with the leaders of the people; and those who cavil at the decision of Parliament on the Thames Valley Drainage Bill, should take heart of grace, and all strive alike, whether Liberals or Conservatives, to educate their party, if they ever hope to grapple effectually with the sewage monster.

At this juncture, neither Parliament nor the public are in earnest, whilst the Circumlocution-office in Whitehall stands with folded arms, waiting, peradventure, for a more convenient season than the eve of a general election, or for a new revelation in the guise of another national pestilence.

COURSE OF INQUIRY AS TO WORKS OF SANITATION, AND AS TO THEIR EXPENSE AND RESULTS.

By Edwin Chadwick, C.B.

On the occasion of my attendance at the Sanitary Congress on Hygiene, held at Brussels in 1877, I had the honour of some communication with his Majesty the King of the Belgians, who takes a special interest in the means of improving the health of the population. In answer to the inquiries as to results practically obtained from sanitary works in England, I submitted that it would be more satisfactory, with a view to any practical application in Belgium, if they could be examined and reported upon by Belgian sanitary officers; and I volunteered my services in aid of such examinations, and in pointing out defects which subsequent experience had shown to be removable. This suggestion was acted upon, and Dr. Kenrurd, an officer of the Health Department, was sent over to make the inquiries suggested. We visited Croydon and Bedford together, and received every aid from the authorities there. The following is a copy of a joint report on the course of the inquiry, and of the results obtained. These. I consider to be to some extent incomplete, as respects some important particulars, which arose from the circumstance of the Belgian officer not speaking English; and being a medical officer, conversant with curative rather than preventive science; and not being able to put the questions for himself as to the details of work, I have suggested that, for further and more complete examination as to works and their application to the Belgian cities, the service of a sanitary engineer would be requisite.

For such a course of examination, the first objective points were, to ascertain—First, what had not been done; next, what had been done only imperfectly; and then, what had been done, and might be repeated completely. I have recommended to the Indian Government a similar course of inquiry, and have volunteered to assist any of their officers for its prosecution, for the avoidance of such losses as those of which we have widely-spread examples, of waste from works on utterly false principles, as well as from the misapplication, or the defective execution, of works on what I deem the sound principles, most fully elaborated under our Sanitary Commissions, and under the first General Board of Health. In our Colonies, and in the United States, there has been extensive, wasteful, and pernicious error in works for the sanitation of cities, which have failed in the commensurate reduction of sickness and death-rates that would have been insured by complete works. Mons. Mille, the *Ingénieur-en-Chef* of Paris, in a report on the sanitary works of Berlin, states that they had been derived by the German engineers from a study of the works devised by our Board, and we know they had visited England for the purpose. The works now in progress in Berlin were devised upon such study, and it is to be hoped that they will present examples of its completeness.

CROYDON.

We visited Croydon, where we had the advantage of the information of Dr. Carpenter, a distinguished physician and for twenty years a member of the Local Board of Health, who, having paid very special attention to the sanitation of the district, is considered to be well versed in the sciences applicable to it. With him, we visited the sewage farm, and saw and received information from the farmer. We also made inquiries on engineering points, from Mr. Walker, the engineer at present in charge of the district. From these sources we received an outline sketch of the sanitary position of the district, which has been filled up by subsequent inquiries as to some of the particulars.

Croydon is about 10 miles from London, and, as it can be reached in half-an-hour by railway, it is almost a suburb of the metropolis. It is, however, in fact a city with a population between that of Bruges and Liege, or about 66,000. In 1879, in consequence of the low state of health of the population, denoted by a death-rate of 28 per 1,000, notwithstanding its advantages, and, in many respects, open position, it was made the subject of an inquiry by the First General Board of Health. It was subject to severe epidemic visitations. The general causes of insalubrity were then stated to be—inferior water supplies, bad drainage, the encombrement of the houses, the surface of the streets, and the supersaturation of the subsoil with wet and excrementary matter. The principles of the remedies recommended by the General Board of Health were—constant supplies of better water carried into the houses, the foul or waste water to be carried away from the houses by a system of self-cleansing house-drains and self-cleansing sewers, and the constant application of all the filth as manurial water for, vegetable production, upon the land. The application of these principles by special sanitary works was unavoidably left very much to the local authorities. It has been the subject of complaint that they have been applied by them in a very unskilful, defective, and expensive manner; nevertheless, it is admitted that, to the extent to which they have been applied, they have been productive of considerable advantage. The reputation of the new works rendered residence in the town popular, and contributed to nearly a fourfold increase of the population, since that time when it was only 18,000. Had the sanitary condition of the town remained as it was, the sanitary evils must have been considerably aggravated, residence in it rendered more dangerous, and the increase could not have gone on. In 1866, an official inquiry was made into the results obtained, when it appeared, on a comparison with those of the six years preceding the new works, that the proportions of cases of continued fevers had been reduced from 16½ to 5 per cent.; of diarrhœa, from 10 to 7 per cent.; of measles, from 8 to 3 per cent.; of scarlatina, from 8½ to 7 per cent.; of phthisis, from 59½ to 49 per cent.; and of the general death-rate, from 237 per 10,000 to 120. It is still considered, however, that the extent of fever and the occurrence of epidemics in the town is a just subject of complaint, and that this arises from the continued defects of the works. The present position of the drainage works is shown by the following questions put to, and the answers given by the engineer:—

Q. It appears from the stated accounts, that at the time when Croydon was brought under the cognisance of the first General Board of Health, there were only 300 water-closets. Of the 14,000 houses, how many are now water-closeted?—*A.* All.

Q. Within what time, as far as you can judge, will the excreta of the morning be taken from these 14,000 houses, and a population of 64,000, to the main outfall? —*A.* The bulk of it would be discharged in about one hour, but from the farthest point, which is about three miles, it would be about four hours. The whole, then, would be discharged in about a quarter of a day.

Q. Is the whole system of pipe sewers now perfectly self-cleansing, or free from deposit?—*A.* We have exceptional cases where that is not so, arising from defective work, from bad joints (which let out the sewage and leave deposit), and, in some places, from the bad laying of the pipes—too level, with too little fall. We are now relaying them. In some instances they were so unskilfully laid as to run the wrong way. Some of this work was done by the owners, who employed unskilful hands. Much of the piping, too, was laid, without due precautions, on "made ground;" that is to say, on strata disturbed for building operations, and sunk out of level or broken from want of proper support, such as it has been the practice to give by bedding in concrete.

Q. If the entire work were done *de novo*, and with the present experience, would not the whole system be made self-cleansing?—*A.* Certainly. We should do the work much better, with better falls and better joints.

Q. Then you would have the whole perfectly self-cleansing, even on dry-weather days?—*A.* Yes; certainly.

Q. How as to the house drainage?—*A.* Much of it is very defective, but we are improving it. In many of the houses, the imperfect jointing of the pipe-drains allowed fæcal matter to permeate the basement and the site. Others have had old brick-drains, and defective work of various sorts.

In answer to further questions, it was admitted that, sanitarily, it is far more important to have self-cleansing sewers, the putrid and decomposing deposit within the house having a more direct action by the discharge of noxious gases than the putrid deposit outside the house in the sewer.

Q. It has been stated that, wherever there have been cases here of a typhoid character, there has been invariably some connection with bad drainage work, inside or outside the houses.—*A.* As a general rule, that is undoubtedly so.

Q. Then it will follow that, for the proper protection of a city, or the proper completion of a system of water carriage, there must not only be a complete system of self-cleansing sewers, but a complete system of self-cleansing house drainage?—*A.* Evidently.

Q. Do you exclude storm-water from your sewers? —*A.* Yes, as much as we can, and we are extending duplicate sewers for the purpose. We are doing this in order to reduce the bulk of the sewage in times of storm, and to render it more manageable for agricultural use. Some time since storm water was not excluded, but we have found out our mistake.

Q. As to the cost of the water-carriage system, if it were done *de novo*, including the supply of the house, the internal apparatus of water distribution, the return of the waste or foul water from the kitchen sinks and water-closet, would it amount to more than threepence half-penny per week?—*A.* Since the tubular system of drainage was introduced, the price of labour has been increased, but the price of the materials, the earthenware pipes and iron, have been reduced, and it may be taken at little more than that.

Q. In addition to this work of water-carriage, there is the cost of the removal of the cinders and solid refuse, which was not removed by water-carriage. How much does this cost?—*A.* The cost of this removal, fortnightly, is about 3s. 4d. per annum per house. This would amount to about ¾d. per week.

Q. A number of distant cottages are cleaned on the tub system, which includes, it appears, the fæces. How much does this cost?—*A.* The cost of this removal weekly is £1 per annum, or 4½d. per week, but this does not include the removal of the liquified refuse of the house, the kitchen slops and the fouled water which, after passing through a filter, is there passed into the river.

Q. Under this system the fæcal matter is necessarily retained for days, *i.e.*, for a time when it must often enter into putrefactive decomposition?—*A.* Yes, for I am unaware that they use any disinfectant, except it be sawdust.

Q. In the case of the water-carriage from the water-closet, the removal from the chamber or from beneath the house is within the minute?—*A.* Yes, certainly.

It is to be explained that the whole of the water distributed into houses, here and in London, averages 33 gallons per head of population; or, as there are usually five persons to each house, there will be 165 gallons per house carried in; and when the tubular system is impermeable and complete, the same quantity, or 1,650 lbs., must be carried away as fouled water out of the house and beyond the site of the city. By the water-carriage system, this is accomplished at a rate of a halfpenny a day. Half that quantity would be beyond any ordinary domestic labour to accomplish, but of this mass of liquid the water-closet consumes, for the work of the removal of the excreta, not more than some five gallons to remove about 2½ lb. of excremental matter per head of the population, or about 12½ lb. per house. Mr. Robert Rawlinson, the chief sanitary engineer of the Government, has stated that the expense of a soil-pan of the nature of a water-closet, with the soil-pipe attachment to the drain from the waste or fouled water, or the sink, may be placed for £1 10s. each. The interest on this extra construction, and the expense of the extra quantity of water used for the closet, may be reckoned at 2s. per house per annum; that is to say, at about one halfpenny per week, or little more than one-tenth the expense of removal here, by hand labour, with the cart and the tub, after the sale of the manure carried away in the solid form, in which form the farmer pays 2s. 6d. per ton for it.

The Rivers Pollution Commissioners, on analysing the effluent water of cities which were all water-closeted, found that the proportion of the manurial matter was about one-fifth more in quantity than the refuse from the non-water-closeted cities. Four-fifths of the manurial matter of the house consists of the kitchen refuse, dish washings, soapsuds from clothes washing and personal ablutions, and such other soluble matter as is carried away through the sinks. Four-fifths of the manure of the cottages in question would, therefore, be discharged into the stream.

The difference in the productive power of the special manure from the tub and the whole of the manure removed by water carriage, would be a subject for a distinct inquiry. But the solid manure is used by the market gardeners, or for the *cultures maraichère* or *potagère*, the most productive of agriculture, and they apply it at the rate of 60 tons per acre, in two dressings, per annum.

Whilst the yield of the common agriculture in England is as one, the yield on similar areas from the market garden culture, with such amounts of manure, near Croydon, was stated to be three and a half; but it was stated that the yield of the sewage farm is much greater, and approaches to five. The best grazing land known carries one head of cattle, but the liquified manure farm at Croydon, it is estimated, carries five; that is to say, that the Italian rye-grass, and mangolds, and turnips grown there feed that number of cattle. The quality of the grass is shown by the different quantities of cream derived from the milk produced from different cultures; thus, the proportion of cream yielded from the sewage-fed grass is stated to be about 15 per cent., whilst that given from ordinary pastures is stated to be only about 10 per cent. It may here be observed that Dr. Carpenter has stated, in a report, what is the effect upon the health of the district in which the farm is situated:—"The last return of vital statistics shows that 26 deaths and [illegible] births have been registered as occurring in the sub-district during the past half-year. This fact bears a most important relation to the working of the farm. The neighbourhood is yearly increasing in population, rateable value, and general health, notwithstanding the fact that, during the past year, the farm has had to provide for and utilise the sewage of a very large number of persons who have suffered from typhoid fever—a fever which has been mainly induced in Croydon through an interference with the water supply of the district. The births in Croydon itself, for the month ending April 29th last, have been 96; whilst the deaths have numbered 35, and typhoid is now entirely absent from the list. The farm has, however, utilised and rendered innocuous all the typhoid excreta from more than 1,000 cases, which have reached it since January, 18[illegible] without the least injury to the inhabitants of the sub-district itself; but that part which was retained in badly-constructed sewers in Croydon, and had no opportunity given to it to change the form of its elements, produced much mischief to those who had the misfortune to live upon the lines of the badly-constructed and imperfectly ventilated sewers. My own impression is, still, that the sooner sewage is conveyed to the country, and at once utilised, the better for the town. The receipts and vital statistics now published, I think, prove that it is also no drawback to the land itself. There is one other point worth mentioning as decreasing the value received from the farm; the great amount of water which has had to be dealt with during the past year has decreased the returns. Excessive flushing of sewer, and heavy rainfalls, much of which still passes into the Croydon sewers, have taxed the land to the uttermost. This year will see an improvement in that direction; a large part of the surface water will be abstracted from the sewers and sent into its proper channels. The market gardening, also, has been given up, in consequence of the impossibility of a local board dealing properly with such grounds."

Viewing the internal works of house and town water supply, and house and town drainage, simply as a means of preserving and removing the manures of the town for agricultural production, these points are to be considered, the equable dilution of the manure in the house for its application on the farm, and the equable dilution of the manure derivable from the streets and the roofs of houses. It is considered that in the house there is a loss of manure from the permeation of the site with foul or waste water, through defective drains and sewers, and also an excessive and inconvenient dilution of the surface manure, the horse-dung and other manure on covered surfaces, by the addition of storm-water to the sewers, which, instead of being carried to the fields, ought to be carried to the rivers. Dr. Carpenter states that measures are being taken to reduce the waste of the water distributed for domestic consumption, which is now as high as 40 gallons per head of the population; and by complete measures it ought to be reduced to about 11 or 12 gallons per head of the population.

The feeding of plants with liquified manure, or giving them food and water at the same time, the future agriculture, as declared by De Candolle, is a speciality yet to be cultivated. On the inquiries made as to how it was that, with a cheap method of removing manure and such a cheap method of applying it by water-carriage, and with the attainment of such a superior amount of produce, it, nevertheless, has not been remunerative to the population, the answers were, that in the first place the rents exacted for the use of the land were excessive; namely, that for land of the ordinary rental of twenty-three shillings per acre, £10 sterling was charged against the town. In addition to which, he first works were without befitting economy, and unduly expensive. In addition to which, the salaries and labour expenses were unnecessarily beyond the rates of ordinary agricultural expenses, and, moreover, that the produce comes at different times, and in different quantities to the ordinary agricultural produce, and that the first sales were o a disadvantage, from want of demand at the unacustomed times. "A Local Board," he said, "labours under very great disadvantages in carrying on a business like a farm. The wages sheet alone will prove this, for here is no one whose pecuniary interest it is to keep down the expenses. Idle hands are retained, and every man's hand is against the Local Board, and in favour of the private individual; whilst the managers themselves, as soon as they become aware of the work that is before them, make violent enemies of those men whom hey have prevented from fattening on the rates. But hey make few active friends amongst the better part of the community, who declined to take part in local politics. The result is that, at the next election, the management is changed, and most of the advantages of former experience is lost."

Dr. Carpenter observes further, that these disadvanages would, with others, be avoidable when pointed out for a recommencement *de novo*.

There was in 1875 an epidemic visitation of typhoid fever in a part of the town. At first it was ascribed o the impurity of the water. On an analysis of the water at its sources, it was found to be exceptionally pure, but the source of impurity was in the sewer gases evolved from the putrid deposit in the defective drainage works. The pipes for the discharge of waste water were often made to open into the sewers or the drains. On the occurrence of certain atmospheric conditions, which occasion an unusually copious evolution of the gases of putrefacion, these gases extend through the waste water-pipes of the butts or cisterns, and being there very much retained by the lids of the cisterns, are rapidly absorbed by the water. A sewer epidemic, in a prison of the highest ordinary condition of health, and recent examinations, have shown that fatal cases of fever occur more frequently from the unskilful conditions of drainage works than has hitherto been suspected.

Dr. Carpenter states that, when the recited defects are removed, and other objects are attained that come within the recognised province of public sanitary authority, such as the prevention of overcrowding, he better cleanliness and ventilation of common schools, which are the centres of children's epidemics, that, without interfering with the ordinary habits of the population in other respects, a further reduction of the deathrate in Croydon, from 17 or 18 to 14 per 1,000 may be effected.

[Dr. Carpenter now states that much of this has been effected, and that during the past 12 months only about four fatal cases of typhoid have occurred in a population of 66,000 people.]

Dr. Carpenter points very emphatically to the experiences there of the removal of excreta, by the method very popular with small landlords in town councils, and with ill-informed persons, by the tub system, which s in every way inferior, and ten times more expensive, than the system of removal by water-carriage, through self-cleansing house drains and self-cleansing sewers; and that as a mere matter of economy of transit, apart from the objection to the retention of decomposing matter about the premises. When the system of waterclosets was introduced by the first General Board of Health as a measure for the entire urban populations, t was violently objected, as it is now objected to for Indian cities, as so repugnant to the habits of the s masses, sure to be misused by them, and as being impracticable. Yet in this city, as in others, it has been brought into general use by all classes, to the very lowest, without complaint or objection on the score of misuse.

The failure in the apparatus was not from its misuse, except in solitary instances, by the people; but from ignorance on the part of architects and builders, the creation of drains and sewers of deposit, and from the ignorance of the local authorities in seeing that the ratepayers' money was properly expended, and the work properly done.

A practical test of the underground work is, to have marked substances put in at the head of the works, and see whether they arrive in due time at the outfall. If they do not arrive, it shows that they are detained somewhere; and if so, that there has been failure in design for which engineer and contractor ought to be made responsible, and compelled to take up the work and complete it in a proper manner before payment is made. Bad engineering and bad work may everywhere be detected by the nose, by the escape of foul smells.

The experience of this city, it was acknowledged, exemplifies a common practical conclusion, that the internal house apparatus for carrying water into houses, and the internal house apparatus for carrying the fouled water out of the house and into the common sewers, should form part of the general system of water supply, and should be provided from a public rate, and be kept in current action, for the common security, under a public supervision, to ensure efficient and economical action in the interest of the general public.

We visited the farm, and inspected the condition of the sewage, as it was passed on to the land from the town sewers. It was then in the condition of a chocolate coloured fluid, but without the factor of advanced decomposition. After having been spread over the land and amidst the vegetation, it permeates through the stratum, and is carried by permeable agricultural drains to an outfall. The stratum of soil with the vegetation forms a great filter. When discharged at the outfall from the land, the sewage was a pellucid stream, deprived of all the fibrous or colouring matter as discharged from the town, and was stated to be purified, as tested by analysis, to an extent that rendered it legally admissible to the river. As another test of efficiency of the process of filtration through the land, it was stated that the river was now particularly well stocked with fish. On this point of river purification, no suggestion of improvement was heard. The object of recent legislation was fully attained.

BEDFORD.

We visited this town, which contains about 20,000 inhabitants, living in 3,500 houses, and is deemed a fair example of a town cleansed under the new system of water carriage, with a direct application of the liquified or the sewer manure to agricultural production on a farm. We were attended by Mr. George Hurst, a gentleman who is an active member of the local board, and of the Association for the Promotion of Social Science, and also by Mr. Lund, the town engineer, and by the manager of the farm.

The site of the town is on deep gravel; the houses, not unusually overcrowded, are widely spread, and it was one not the most prominently needing sanitary improvement, but the wells were beginning to be polluted by fæcal matter, when it was determined to have a new supply of water—not a river supply, but a spring supply —distributed into all the houses, and to have all the fouled water with the fæcal matter in solution distributed on an adjacent farm. And this was done. All the houses, except some detached outlying houses, are now water-closeted. All the excreta from them is now in course of instant removal from the site of the houses and of the town, and in a very short time (within an hour or two) it is upon the land. Mr. Hurst stated that the result of the work had, on the whole, been satisfactory to the town. The previous death-rate had been about 24 in a thousand annually. The last year had been a year of exceptionally high mortality, and it was 19 in a thousand, but in the previous year, it has been about 18 in a thousand, so far as could be ascertained from not very clear statistics.

Accepting what has been done as an improvement, the object of the inquiry was to ascertain what has been the shortcoming in results and in expense, and how much further the improvement might be carried if the work had to be begun *de novo*, with the advantage of past experience.

As a sanitary test point, the engineer was asked whether all the sewers were free from smell, from the smells of decomposing matter or sewer gases? He admitted that they were not entirely so.

Were they not, then, completely self-cleansing and free from deposit? Some portions were not. About one mile out of sixteen was badly laid, let water out at the joints, and occasioned deposit to be accumulated in the sewers; hence decomposition and sewer gases from them.

How as to the house drains, were they completely self-cleansing? It was admitted that the drainage work of many of the houses were very defective. They had been badly done by private builders.

[It is proper to explain, that the defects in the sewer work were defects understood to be of the predecessor of the present engineer, and neither for those nor for the defective house drains was he responsible, and therefore there was no delicacy needed in questioning him about them. Though the defective sewer work formed only one-sixteenth part of the whole system, yet to that extent it formed stagnant cesspool, giving off noxious emanations, which, together with the defects in the house drains must permeate at times, and in certain barometric conditions the whole line of sewers, and distribute sewer gases into the house, and through the openings into the streets. Nevertheless, it is to be borne in mind, that the whole was previously in the condition of that sixteenth part of the system.]

As to the water-closets, or the soil pans in the houses. How were they used by the poorer classes of the people? Very well; the pans, as a rule, were kept very clean. If there were any defect or interruption in the means of cleansing or of the water supply, the housewives were very prompt and sharp-tongued in their complaints to him (the engineer) about it.

As to the supply of water for domestic consumption what quantity was distributed? About 20 gallons per head of the population.

Twenty gallons per head of the population! One hundred gallons per diem per house for such a place as this, a quiet rural town, was not that really in excess of the actual consumption, and a waste? Yes it was, yet it would, by better supervision of the house service pipes, be probably reduced by one-fourth, or to fifteen gallons per head of the population.

The inquiry on this topic of sanitation led to the examination of the effect of the commercial value of the sewer water, as experienced at the sewer farm.

It is to be explained, that the quantity of manure fæces and urine is now taken as a constant, at two pounds and a half per head of the population daily—men, women, and children. With a view to keep the dilution equable, for transport and application as manure, the first General Board of Health endeavoured to get water-closets, which are cleansed with little amount of water; and it was found that constructions were to be obtained, which were self-cleansing, with little more than half a gallon, or five pounds of water, added to the fæces. But little regard was paid to the eventual disposal of the fæces as manure, and water-closets have been adopted which worked with three, four, or five times the quantity needed as a carrier. One requirement of the first General Board of Health was, that all the putrescible refuse of towns should be conveyed away in impermeable channels, generally of glazed pot pipes, and rain water, except from the covered surface of roads and streets, which had much manurial matter from the droppings of horses and other animals; but that the rainfall upon gardens and other uncovered surfaces, and all storm water, should be removed in separate channels: the subsoil land water by permeable agricultural pipe drains, and carried away to the river.

These requirements have, however, frequently been disregarded by the local and other insanitary engineers and the channels were formed to remove storm water as well as the ordinary rainfall. Being made to remove storm water, they are made of much larger size than is necessary to remove the ordinary house refuse, which in dry weather days, is spread over a very wide surface, by which friction is increased, the flow retarded, and deposit occasioned, and stagnant putrefaction generated, to the deterioration of the manure, as well as the general health. To some extent, this appeared to have been occasioned here. The excessive dilution of the manure by the unnecessary waste of water in the closet, and still more by ill-fitting service taps, was not so injurious as the excessive dilution of the manure by the outside rain and storm water. This excess so reduces the quality of the manure that it has in numerous instances, been declared to be in amount of the value of one halfpenny per ton when put upon the land. The position of agriculture, in relation to the internal drainage works of a town under the new system of drainage works, is denoted by an action brought against the authorities of another town for damages for non-fulfilment of a contract. The town had been newly drained, as was held forth to the plaintiff, on correct principles, and he contracted for the whole of the sewage, or liquified manurial matter from it, and took a farm and formed works for its application. But he found that the sewage received was not in the quantity, or of the quality that it ought to be from a well and completely drained town: much of the town was left undrained, and, of the part drained, the work was, he alleged, badly done, by which he has sustained damage, for which he demanded compensation from the Court of Justice. But the public exposition of the case has been lost by a compromise.

There can be no doubt of the strong interest which agriculture has, concurrent with those of the town, in the immediate and complete removal of all excrementary matter, in the cheapest manner, by perfect internal drainage works, before it can enter into putrefactive decomposition. The formation of the excessively large sewers adds enormously to the expense of the internal drainage works, and, it must be added, adds to the profit of the engineers who persuade the town to undertake them. In the instance of this town there did not appear to be any flagrant excess in the cost of the works. But the error of the admission of storm water into the sewers, and the necessity of its separation in the interest of sanitation, as well as of agriculture, was admitted by the engineer. The channels for the removal of the sewage proper would, he said, be made smaller, with some reduction of expense, counterveiled by the expense of separate works for the removal of rain, of subsoil, and of storm water.

Notwithstanding all deductions, however, the agricultural produce from the liquified manure of the town, is in advance of any other. The sewage, in the instance of Croydon, was applied to a dairy farm, chiefly for the production of milk. The sewage of this 20,000 population of Bedford is applied to 180 acres, chiefly of market garden culture, distributed as set forth in the account of the sales for 1876. (See Table next page.)

But it may serve for comparison to state the weights per acre of the chief crops, which have been as follows:—

	Tons per acre
Italian rye grass per crop, sometimes cut four or five times a year	25 to 30
Potatoes	12 to 15
Carrots	24 to 30
Onions	12 to 16

IRRIGATION FARM.—BEDFORD, 1876.

Description of Crop.	Acreage.			Average Per Acre.			Total Produce.		
	A.	R.	P.	£	s.	d.	£	s.	d.
Italian rye grass.....	30	0	0	12	8	1	372	2	6
Grass, permanent pasture.............	30	0	0	7	8	3¾	222	9	2
Wheat.............	10	1	0	6	11	3¾	67	6	1
Oats...............	12	0	0	9	14	9	116	17	0
Beans...............	4	3	0	13	1	0¾	62	0	0
Mangolds	38	0	20	14	0	8¼	535	1	3
Onions............	11	0	10	32	8	5¾	358	13	9
Carrots	16	0	0	10	4	9¼	163	16	4
Potatoes...........	10	0	0	11	2	2	111	1	6
Cabbage............	6	0	0	13	8	10	80	13	0
Savoys.............	3	0	0	14	13	11	44	1	9
Pickling cabbage	2	2	0	10	0	11¼	25	2	4
Cauliflowers........	2	0	0	18	6	6	36	13	0
Kidney beans.......		3	0	16	0	0	12	0	0
Celery.............		3	0	53	4	4	38	8	3
Cucumbers..........		3	0	18	13	4	14	0	0
Vegetable marrows..		1	0	16	14	0	4	1	0
Asparagus			20	36	0	0	4	10	0
Rhubarb............			20	32	0	0	4	0	0
Currant trees, &c. ..	2	0	0	5	0	0	10	0	0
	180	1	30				2282	16	11

There are some market garden farms in the neighbourhood of Bedford which are considered to be very good of their kind, which, in yield of produce on equivalent areas, is considered to be more than three-fold the common agricultural produce, but the sewage farm approaches to a five-fold yield. There are some cottage allotments held by the wage classes on the outskirts of Bedford, which are highly manured with pigs, and other manure, and worked without stint of labour, but they by no means attain weights grown on the sewage farm. The liquefied manure culture exceeds them all in quality as well as in bulk. There is an increase of saccharine matter, in the carrot, for example, with an aroma which make it almost a new root for table. By reputation, the like characteristics make the produce of other sewage farms. On one sewerago farm the rhubarb is so superior that it is used for making a champagne, and a wine of the character of a "still hock." The garden and fruit farms, it is acknowleged, required a more refined culture than the ordinary agriculture, and so it is evident do the diverse cultures of these liquefied or sewerage manure farms.

A question has been raised as to the necessity of a chemical treatment of what is called sludge, namely, the paper, rags, and other fibrous matters discharged from the water-closets and house drains into the sewers. But here there is no difficulty in dealing with it advantageously. It is dealt with as solid manure, and worked into the land, and is found to exercise a high fertilising property for about two years. About two and a half per cent. of the space of land is found sufficient to utilise this refuse satisfactorily. But it is objected that this and others of these sewage farms are unremunerative, and truly they are very little likely to be remunerative while expensive engineering works, so much beyond the agricultural economy, are charged against them, together with the internal works of the town drainage, however extravagant. In the instance of this farm, is is contended that, inasmuch as it would be requisite to pump the sewage out of the town if it were thrown into the river as worthless, the cost of pumping, amounting to £360 a year, ought not to be charged against the land. Moreover, it is charged with an exaction of £5 an acre, or more than double the average rent of the best agricultural land in that vicinity. On a fair adjustment of the expenses, the farm is at present deemed to be remunerative. A commission of inquiry was recently held on the different modes which had been allowed to the town councils of treating town sewerage. The Commissioners of inquiry were Mr. Robert Rawlinson, C.B., the chief consulting engineer of the Local Government Board, and Mr. Clare Reed, an eminent agriculturist and Member of Parliament. They concluded, as repeated official inquiries have done, in favour of the direct application of the sewerage to the land. It may be objected that they took too lenient a view of the cost of the engineering works, and of the defaults of the official supervision due to the ratepayers, and were otherwise apologetic for failures from want of skill. They state that "the successful management of animals, and the proper cultivation of crops, require a fair amount of intelligence and experience, but successfully to carry out all the details of these matters upon a sewage farm, where there is so little to guide the practical farmer, and so much to confound his past experience and upset his previous calculations, is indeed, a hard task. And, as most sewage farms are at present under the control of ever-changing town councils and members of local Boards, whose members must as a rule be ignorant of practical agriculture, and whose theories upon the subject may be wild and visionary, is it surprising that such poor returns have hitherto resulted from the application of town sewage to the growth of crops? Disappointment has, therefore, been expressed at the very poor financial results of sewage farms. Agriculture is never a specially lucrative business, and during the last few years it is probable that strictly accurate accounts would prove that very little profit has been derived from the ordinary cultivation of arable land. Farms to which town sewage is applied have invariably many unfavourable circumstances to contend with. The rent, except where the local authority has land of its own, is certain to be extravagant; the application of the sewage is often too costly; the management is frequently changeable and faulty, and the prejudice against the produce of the farm is, in some districts, obstinate and widespread. But, where a fair rent is charged on suitable land, where the sewage is cheaply and regularly delivered, and a good market is close at hand, there is no reason to doubt that the return for capital judiciously expended upon sewage farms will produce a higher rate of interest than the money invested by the majority of the village farmers throughout the country."

Exception is to be taken to the assumption countenanced in this conclusion, that the work of sewage-farming is the work of the general agriculturists, whereas, as stated, the work of very special horticulturists.

The quantity of land needed to utilise sewage varies considerably with the soil and the culture. But it may be stated, as an approximation, that an acre will suffice to utilise the sewage of 100 of population, or a hectare for every 200 of population.

The modes of distributing the manure on the surface differ considerably, and, for practical application, it would be worth while to have comparisons made, with working drawings of leading instances, by a competent engineering draughtsman.

So also as to the sizes of house drains and sewers, on the close adaptation of which to the service for which they are required, so much of sanitary efficiency and economy depend, the formulæ in engineering works require the correction of further observation. One practical conclusion, from the experience of grievously defective works, is that attention should be recalled to original suggestions that the contractors, or the sub-contractors, should be bound to maintain them in complete working order for a year or a term, and to relay immediately any drains or sewers which occasion deposit, and emit noxious smells. So also that works should undergo a strict official examination to ensure the exact performance of the contract, and that the works are of a nature to ensure, and be of benefit equivalent to the charge.

In respect to the cost of the internal works of water distribution, the engineer here was of opinion, with that given at Croydon, that the increase of the price of labour, and the reduction of the prices of materials, rendered it difficult to give more than wide approprximations ; but that for works began *de novo* they might be taken to be, as a public service :—

	Per Week.
For bringing a constant supply of water to the door of every house	1d.
For taking into the house	1
For removing the fouled water from every house	1
For the service of the water-closet	0½
Total	3½

or a little above that rate of charge.

The lowest estimated supply here is 15 gallons per head of the population, or for a household of five, more than 500 gallons of liquid, carrying upwards of 100 weight of excreta per week. No human labour, not the cheapest labour of the Hindoo cities, can compete in cheapness with water-carriage.

To this economy, however, is to be added the economy of human life, and the saving of the loss of productive force from excessive sickness. With all the shortcomings of the sanitary works, the daily immediate removal by the present system of 3,125 tons of sewage, including the rainfall, with putrescible matter, from within the town, may be credited with the reduction of the death-rate from 24 to 18 per 1,000, or 6 per 1,000, or 120 deaths annually ; and for every preventible death some twenty cases of preventible sickness are estimated. In whatsoever way the pecuniary economies of this class were estimated, it was found greatly to exceed the outlay on the new works, even if no return had been derived from the increased agricultural production.

Preliminary inquiries have been made as to other towns, fraught with indications of important results for future guidance as to central and local administration, as well as to works.

WORKS OF SEWERAGE AND SEWAGE DISPOSAL.—CROYDON RURAL SANITARY AUTHORITY.

By Baldwin Latham, C.E., M.Inst.C.E., F.G.S., F.M.S., &c.

For some years past the Croydon Rural Sanitary Authority have had forcibly brought to their attention the necessity for a complete system of sewerage and sewage disposal for Beddington, Merton, Merton Rush, Mitcham, Morden, and Wallington, being parishes or places under their jurisdiction for sanitary purposes.

The aggregate area comprised within these districts is 10,106 acres, or nearly sixteen square miles. The population at the present time is about 16,000, but it is very rapidly increasing, and since 1851 has more than doubled. Several centres of population are located in the drainage area, but at considerable distances apart.

Geologically, the district embraces the various formations found in the neighbourhood of London, and lying over the chalk, which is the lowest geological formation in this district, and finishing with an alluvium overlying the London clay.

Naturally, the district drains to the Beverley Brook and the River Wandle, both of which streams flow in a northerly direction, and ultimately fall into the River Thames within the metropolis. The natural falls of the district are towards the metropolis, and as the district in question is contiguous thereto, it was a matter of some difficulty to provide an economical and sufficient scheme for effectually treating the sewage when a system of sewerage came to be carried out. It was considered that the cost in lifting the sewage, and carrying it a considerable distance in such a district, was quite out of the question, but ultimately a scheme was adopted, and is now in course of rapid execution, by which sixth-sevenths of the whole of the sewage of the combined districts will be conveyed by direct gravitation to land located partly in the parish of Wimbledon, outside the jurisdiction of the Croydon Rural Sanitary Authority, and partly in the parish of Mitcham, within the jurisdiction of the Rural Sanitary Authority.

An area of 38 acres of land has been purchased, by agreement, for which a sum of £11,700 was paid. Thirty acres of this land is an alluvial deposit, principally gravel, through the centre of which formerly ran the old channel of the river Wandle, the remaining eight acres being stiff brick earth. In order to convey the sewage of the district to the proposed area, 36 miles of sewers are required to be constructed. Of these 36 miles of sewers, 29¼ miles are ordinary socket pipes, jointed with tarred gasket and Portland cement, varying in size from nine inches to 18 inches in diameter, and five miles of earthenware pipes with Stanford's patent joint. The latter also vary in size from nine inches to 18 inches in diameter. There will also be 1¾ miles of brick sewers, 24 inches, 27 inches, and four feet in diameter. The four feet sewer is to be used as a tank sewer in connection with that portion of the district, the sewage of which will not flow by direct gravitation on to the land, and it is made of the size in question in order to hold the sewage during the night, or at any period when the engines may require to be stopped. The sewage of one-seventh of the whole district, will require to be pumped to a height of 25 feet, including friction. It will then pass with the sewage from the gravitation area through a series of tanks, in which the solids will be deposited, and the liquid will then flow on to the area of land laid out for filtration. The land which is now being prepared for filtration is an alluvial bed 30 acres in extent, but as this land is entirely surrounded by rivers and streams, and is extremely porous, in order to fit it for sewage purposes, it was deemed advisable to form all round it a puddle wall, which is carried through the alluvial bed of gravel and porous soil into the London clay lying below, and thus shut out the adjoining waters, which have hitherto percolated into the land, and made it a swamp. A main arterial drain is carried through the centre of the land, and subsidiary drains will be made, by which the whole area within the puddle walls will be made the freest possible filter for purifying the sewage which is to be brought upon it.

The tanks for freeing the sewage from the solids are so arranged that chemicals may be used for producing precipitation before the application of the sewage to the land. It is not, however, contemplated to use chemicals directly to the sewage. Owing to the position of the works with reference to the contiguous population, and having regard to the desirability of preventing the slightest nuisance, the tanks for treating the sewage are placed under cover, and the solids or sludge, which will be removed by subsidence from the sewage, will at once be consolidated. For this purpose the sludge will be received in a lower tank than the filter tanks, where it will be treated with lime, so as to destroy its adhesive properties, and then be forced through filter presses, so as to consolidate it ready for immediate removal.

Experiments have been made with reference to the purifying properties of the area selected for filtration. Some portions of the soil of this area, in its natural state, are not so efficient as might be desired, when compared with other lands well known to be suitable for the filtration of sewage. There is no better way of testing land as to its fitness for sewage filtration than by ascertaining the per-centage of water, by weight, it is capable of temporarily holding without loss. The most unfit parts of the area at Mitcham have been tested with the following results:—

			Per cent. of water absorbed.
No. 1	Sample,	Yellow clay	53·3
,, 2	,,	Loam, sandy	50·2
,, 3	,,	Peat	120·0
,, 4	,,	Loam	62·0
,, 5	,,	Loamy soil	60·0

If the above samples are compared with the characteristics of well-known lands adapted for the purification of sewage, it will be seen that they are greatly inferior to some of the following:—

	Per cent. of water absorbed.
Surface soil of the Merthyr filters at Troedyrhiw	39·82
Subsoil ,, ,,	45·77
Another sample of subsoil	37·48
Additional land at Merthyr for the reception of the sewage of Aberdare—surface	49·05
Ditto, immediately below surface	41·35
Ditto, subsoil	13·07
Beddington sewage farm—surface	50·0
Norwood sewage farm—surface	59·0
Ditto, subsoil	41·0
Dursley soil (well known for its purifying powers)	34·0
Chorlton Ees, near Manchester—surface	56·71
Same soil after being burnt into ballast	36·55

The porosity of soil, or the power to allow water to pass by filtration, is inversely in proportion to its capacity for retaining water. With rocks, however, it is the reverse, the smaller the per-centage of water rocks will contain, the more dense and impenetrable they are to water. Clay soils, when burnt into ballast, differ in their physical properties very little from the Dursley soil, which was experimented upon by the Rivers Pollution Commissioners with such satisfactory results, and the experience of late years has shown that this material, when used as a filter, is well adapted for the purpose of purifying sewage, and so in districts where clay soil only is to be found, this material may be made into artificial filters, which will have a greater purifying power than is the case with almost any natural soil, perhaps with the exception of Dursley soil, which, in its colour and characteristics, is not unlike burnt clay.

The eight acres of clay land that have been acquired by the Croydon Rural Sanitary Authority, when made into artificial filters, can be made to effectually purify the sewage of about twenty thousand people. The unfavourable position which peat occupies in reference to its retention of water is confirmatory of the experiments of the Rivers Pollution Commissioners, who showed that it was about the worst material that could be selected for a filter, and in the case of the Croydon Rural Sanitary Authority's works, will require to be entirely removed, and a more efficient material substituted.

The total cost of the Croydon Rural Sanitary Authority's works is estimated at £96,000. This amount, however, will no doubt be exceeded, as there are many new streets now being formed in the district, all of which it will be necessary to sewer. The cost to the present ratepayers of the district will be entirely covered by a rate of 15d. in the £, which includes the working expenses and the repayment of the principal and interest. No allowance is made for any returns from the land to which the sewage will be applied, and the rate includes the interest and repayment of the principal for the purchase of the land. There will, however, be a considerable return from the land, which cannot, in this neighbourhood, so near to the metropolis, be put down under from £15 to £20 per acre as the value of the crops, which would not be all profit, as the cost of cultivation must be deducted; but even if the cost of cultivation equalled the value of the crops, it is true economy to utilise the sewage, when compared with the system adopted in the metropolis, and now extending to other places adjacent, of removing the nuisance from one spot to another lower down the same river. As the district of the Croydon Rural Sanitary Authority is fast increasing, both in population and rateable value, there is every reasonable probability of the rate being lessened. If the cost of these works is compared with the cost which has been incurred in adjoining districts, in which the sewage is disposed of by being collected into arterial drains, and then thrown into the Thames, it will be seen that the whole system of sewerage, with its works for purifying the sewage, will cost the ratepayers of the district but a tithe of the amount the ratepayers of adjoining districts have to pay for simply constructing the outfall sewer only. This is a strong example of the economy of locally treating and purifying sewage, rather than shifting a nuisance, at great cost, from one point to another, from which some day it will have to be removed at still greater cost.

SOME EXPERIENCES OF SEWAGE EFFLUENTS, AND BURNING SLUDGE INTO CEMENT.

By Granville Cole, Ph.D.,

Late Student under Drs. Frankland, Hofmann, and A. Claus, Member of the Berlin Chemical Society, &c.

During the past year, it has been my duty to watch the process for purifying the sewage now being carried out at Burnley, in Lancashire.

1. In a paper, which was read by Mr. Richards last year at this Conference, the method of dealing with water-carried sewage by General Scott's system of precipitation by lime, and utilisation of the sludge for cement, was described. Examples of this process with the cement are exhibited in the Society's room below.

2. This process has now been carried on for nearly eighteen months. The sewage is purified, and the effluent—samples of which have been submitted for analysis to two of the highest chemical authorities—is certified by one to be fit to be poured into a stream of ten times its volume, by the other to be fit to be poured into a stream, having a velocity of at least three miles an hour, of fifty times its volume. Both these conditions are fulfilled at Burnley.

3. This effluent could be further purified at a comparatively trifling cost to towns by intermittent downward filtration, requiring only one-sixth of the land, which, according to the Rivers Pollution Commissioners' 4th Report, unprecipitated sewage requires.

4. The Corporation of Burnley have not required that this should be done, but the injunction against the town has been suspended. In the case of Burnley, the stream into which the effluent is poured varies very much, according to the weather. In wet weather I have seen the Pendle water, as the stream is called, rise several feet in as many hours. I abstain from giving the many analyses I have made of the effluent water, and comparing it with the averages given by the Rivers Pollution Commissioners. A fair average could only be obtained, in my opinion, after daily observations, extending over a year.

5. The rainfall at Burnley is exceptionally high, and the neighbouring hill, the Pendle, collects and pours the rain into the Pendle water. The Pendle water itself rises not far from the small, old town of Colne, and receives the raw sewage as it flows by. It then flows past the townships of Nelson and the village of Barrowford, on the west of the village of Brierfield, from all of which places it receives more raw sewage before it reaches Burnley. A scheme is now under consideration for the federation of these places, in order to bring their sewage to the Burnley sewage works for purification. Should this scheme be successfully carried out, the Pendle water will certainly be one of the cleanest streams in Lancashire. I have several times noticed that the stream is very much dirtier than the effluent poured into it from the Burnley sewage works.

6. Portland cement is manufactured from chalk or limestone and clay. The component parts of these materials varies very slightly and, therefore, the manufacture is nearly constant. The average analysis of five large manufactories gives the following results, viz:—Lime, 56·21 per cent.; silica, 24·44 per cent.; iron, alumina, 12·1 per cent.

7. The manufacture of Portland cement from sewage is much more precarious. Sewage, according to my experience, varies in every place, and during every hour, and consequently has to be carefully watched in order that the requisite quantity of milk of lime may be added. At Burnley, on certain days, large quantities of dye water come down, on other days butchers' refuse, and once or twice we have observed the sewers full of coal-tar and oily refuse; all these facts have to be carefully observed, and only after careful experiments can the quantity of lime necessary to precipitate the sewage be determined. The resultant sludge at Burnley on an average only contains 46 to 50 per cent. of lime and, therefore, before it is fit to be burnt into Portland cement clinker, more lime has to be added. This is done after the supernatent water has been run off the sludge deposited in the tanks. The sludge has afterwards to be passed through a pug-mill in order that a uniform compound may be obtained.

8. At Birmingham, where Portland cement was also made, the sewage is so capricious that a uniform manufacture could not be guaranteed. This is accounted for, by the fact that at certain times very large quantities of acid from the hardware manufactories of the town are poured into the sewers.

9. At Portsmouth, where I have studied the sewage, which has wholly water-closet and house drainage, there is little or nothing to interfere with the manufacture of a high class Portland cement: I believe the same remark would apply to the lower Thames valley sewage. The sewage requires only a small quantity of lime to defecate it; 16 grains of quick lime per gallon is ample. The sludge I have found generally contains from 58 to 60 per cent. of lime, and, therefore, no fresh lime would have to be added. The fact that at Portsmouth the storm water is partially kept out of the sewers is also greatly in favour of the manufacture of good cement. And in places where the separate system is in force, and where the proportion of water-closets is large, it would be, perhaps, worth while to allow the finely suspended organic matter to subside before liming, and to treat the organic matter described in General Scott's patent.

10. The sludge resulting from limed sewage may also be burnt at a lower temperature than that necessary to produce Portland clinker, and be re-used to precipitate the sewage. After this has been done several times, the lime becomes rich in phosphates, and may be profitably sold as a first-class agricultural lime.

11. As a result of my experience, I have arrived at the following conclusions:—

a. The sewage of every town should be carefully watched and experimented on, before any plans or estimates are made.

b. The storm water should, if possible, be kept out of the sewers.

c. A paved town is more favourable to cement manufacture than an unpaved one.

d. That manufacturing refuse, except acids. does not materially interfere with cement manufacture.

12. In conclusion, I may state that the cement now being made at Burnley is much improved in quality since the manufacture began, and much has been sold. The latest tests give excellent results. Mr. Deacon, borough engineer of Liverpool, reports the tensile strain of 695 lbs. on the 1½ inch square, and that the cement passed through a sieve of 50 meshes to the inch, leaving only 7 per cent. of residue. The latest test at Burnley gives 698 lbs.

13. A portion of a sea-wall at Portmouth has been built with it, and it has stood this test remarkably well.

14. Much has been learnt since the process was first started at Burnley, and it may be fairly expected that towns will obtain purification, and at the same time will recover the greater part of the cost of so doing, by adopting this process.

TEN YEARS' PRACTICAL EXPERIENCE IN SEWAGE TREATMENT.

By Frits Hille, C.E.

The sewage question stands now as it stood twelve months ago, when the Conference of the Society of Arts was held in May, 1878; no progress, no further discovery has since been made in the treatment, utilisation, and in the disposal of town sewage, and, having no further remarks to add to those contained in the pamphlets written by me on this subject, I now submit, as a possible matter of interest to those concerned in or connected with the sewage question, the results obtained during the last ten years from practical every-day use of the method of sewage disposal advocated by me. I shall refer to towns where my system of sewage treatment has undergone the test of time; giving correct statements of cost for labour and chemicals, and other figures and testimonials which show and prove unquestionable success.

WIMBLEDON.

The Wimbledon Local Board, from 1870 to 1876, were entirely free from litigation in respect of the disposal of their sewage, there were no complaints, and my method of treating the sewage gave satisfaction to the authorities.

EDMONTON.

The Edmonton works serve as a model for places similarly situated. The effluent water gives satisfaction to the local and the river authorities, and the sludge has proved no difficulty; the stuff is inoffensive, and as a good manure finds ready customers. The osier beds answer very well.

The system has stood the test of time and of practical every day use very well indeed.

The cost at Edmonton, for a population of 16,000, for chemicals is £4 8s. 10d. per week; or—including wages, pumping, and materials—per annum about £750; royalty, £100; total, £850; or, cost for chemicals and royalty, about £350—equal to 5½d. per head of the population; or, total cost of works about £850—equal to 1s. 1d. per head of the population.

In the beginning of 1878 some eight acres of land were laid out and prepared for watercress beds, to be supplied with the purified effluent from the deposit tanks, and the operation of growing watercress with such water has proved quite a success, so much, that double the quantity of land will be used this year for the same purpose. This land lets at £10 per acre.

A description of the Edmonton Sewage Works is given in my "Remarks on the Sewage Question," of 1877.

I append testimonials from the clerk to the Local Board of Health:—

Edmonton,
December 6th, 1876.

Dear Sir,—I am directed by the Edmonton Local Board to reply to your favour of the 30th ultimo, that they have pleasure in informing you that they acknowledge the satisfactory results of your process now in use at the Edmonton Sewage Farm.

Your process has satisfied the requirements of the River Lee Conservancy Board, and it appears to the Edmonton Board to be at present the best known process.

Faithfully yours,
(Signed) Chas. S. Houlder,
Clerk.

F. Hillé, Esq., Chiswick, W.

TOTTENHAM.

I have treated the sewage of this town for more than three years, and the following letters refer to the result, *i.e.*—

Asplins, Tottenham,
November 6th, 1377.

Dear Sir,—Having used on my farm a considerable quantity of manure obtained from the works of the Tottenham Local Board, I can now give the results. I find it exceedingly beneficial in the production of cabbages, imparting that good colour almost unobtainable from other manures. Tares and rye thrive remarkably well, as also do white turnips. My experience with meadow land last season was of a limited character, but I was so far satisfied that I have lately well manured upwards of 30 acres of grass land, which will enable me, later on, to speak from facts.

As a general rule I do not take any notice of written testimonals, knowing them to be mere advertisements, however, in this case most of the crops are to be seen, and they will speak for themselves.

Yours truly,
(Signed) Wm. B. Delano.

W. A. H. De Pape, Esq.

Tottenham,
3rd June, 1878.

Dear Sir,—I have much pleasure in bearing my testimony to the success which has attended your treatment of the sewage of this district ever since its commencement in the month of February, 1876.

We have since that time had no complaint from the River Lea Conservancy as to the quality of the effluent water we discharge into their river.

We have for some time past had no difficulty in getting rid of the sewage deposit (sludge) which is being used as a manure; and the sewage works have entirely ceased to be complained of as a nuisance by those inhabiting the neighbourhood in which they are placed.

Wishing you the same success in other districts where your system may be applied,

I have the honour to remain
Your obedient servant,
(Signed) Arthur R. Abbott,
Chairman to the Tottenham Local Board of Health.

F. Hillé, Esq.

The cost of chemicals used from the 17th of February, 1876, to the 17th of February, 1877, for treating daily from one million and a half to two million gallons of notoriously bad sewage, amounted to—

For 353 cubic yards of Lime at 13s. 6d. per cubic yard	£238	5	6
For about 1,000 gallons of tar	25	0	0
For chemical salts	208	0	0
	£471	5	6

SOUTHBOROUGH.

The letter underneath speaks for the results.

Southborough Local Board,
8th August, 1878.

Dear Sir,—In reply to your letter of the 7th ult., I am instructed to inform you that for some years past the Southborough Local Board have experienced great difficulty in the treatment of the sewage of their district, so as to prevent any nuisance to the stream into which the effluent water runs, and have tried numerous systems of purification, all of which turned out more or less failures.

It was not (as you are aware) until after the Board had decided upon purchasing land for a sewage farm that your process was adopted at Southborough, and the Board consider that, although the existing tanks are very inefficient for the proper carrying out of your system, such process is decidedly the best of those the Board have tried, particularly as regards the quality of the effluent. The Board are also of opinion that the cost of the process is reasonably cheap, and believe that in many instances (particularly where suitable land cannot be obtained) Sanitary Authorities would do well in adopting your patent system for purification of sewage. I am, dear Sir,

Yours truly,
(Signed) GEORGE DELVES.
Clerk to the Southborough Local Board.

F. Hillé, Esq., Engineer, Chiswick, W.

TAUNTON.

After the Taunton Sewage Works had been three months in operation, on the 28th of December, 1877, at a special meeting of the town council to consider, and after careful inspection and thorough investigation, to report upon the efficiency of the works, and upon the results obtained from the use of my process for the treatment of the sewage, the following resolution moved by the mayor was passed:—

"That the Taunton Sewage Outfall Works have fulfilled the expectations of their promoters and the requirements of the town."

LEICESTER.

The following letters refer to the results obtained at the Leicester Sewage Works:—

Leicester, October 16th, 1877.

We have applied Mr. F. Hillé's patent process for the purification of the effluent water from our sewage works for the months of May to September, both included. Considering the filthy condition of the banks and bed of the river, the fouling of years past, the very limited area of settling tanks, and the small lengths of weirs in proportions to the large volume of sewage passing the works, viz., 6,000,000 gallons per diem, the water in the river was greatly improved by the application of the process,

The [occupiers of lands immediately adjacent to the works, and the occupiers of the Belgrave Lock House, which is surrounded by the effluent water, declare the beneficial effects on the atmosphere, which they all state has not been so free from pollution for 20 years.

The action of the salts is so effective in cleansing the covered tanks, that the labourers employed in emptying them give the process the highest praise as enabling them to do their work without nuisance. I have no hesitation in saying that I believe under more favourable circumstances the effect would be perfect.

(Signed) E. L. STEPHENS,
Borough Surveyor.

Fritz Hillé, Esq., Chiswick.

The Nurseries, Leicester Abbey,
22nd June, 1877.

MY DEAR SIR,—I have been much struck with the beneficial effects of Mr. Hillé's process on the river water adjoining my meadow. I have watched the river daily, and have no hesitation in saying that I have never seen the water during the last 20 years so free from all smell and offence.

I am, dear Sir,
Yours truly,
(Signed) THOMAS WARNER.

E. L. Stephens, Esq.,
Borough Surveyor, Leicester.

As to cost, the figures underneath speak for themselves:—

Cost of Chemicals, Fees, and Travelling Expenses.

1876.	HILLE'S PROCESS.	£	s.	d.
May.	Total cost for Lime, Tar, Salts, Fees, and Expenses	187	9	2
June.	Do. do. do.	164	18	5
July.	Do. do. do.	158	18	3
August.	Do. do. do.	130	0	11
September.	Do. do. do.	135	13	2
	Total.........	£776	19	11

The figures given above show that the total expenditure for chemicals during the five summer months amounted to £776 19s. 11d., or, on the average, £156 per month, including travelling expenses; according to this, the annual expenditure would be about £1,872; but a considerable part of that amount could be saved by a judicious arrangement of summer and winter treatment. The yearly outlay of £1,872 for 120,000 inhabitants represents not quite 4d. per head of the population.

It will be seen, when comparing the cost at Leicester with other towns, that the expense for the chemical treatment of large volumes of sewage according to my plan, is not greater, but rather smaller, in proportion to moderate quantities, for instance—

		Inhabitants.		Per ann.			
Leicester,	with	120,000	at the cost	£1,872	equals	4d.	pro head of population.
Tottenham	,,	34,000	,, ,,	575	,,	4d.	
Edmonton	,,	16,000	,, ,,	350	,,	5¼d.	
Taunton	,,	16,000	,, ,,	300	,,	4½d.	
Southboro'	,,	4,000	,, ,,	100	,,	6d.	

ALDERSHOT.

Reference has been made in my pamphlets to the Aldershot (Town) Sewage Works, which were completed in December, 1877. Since then I have treated the Aldershot sewage, and I am able to state that the sewage works and the plan carried out give satisfaction to the authorities. The total cost of these works, which are large enough to deal with the sewage of 15,000 people, is under £3,000, inclusive of about three acres of land, and comprising, inlet chamber with gratings and screens, valves and storm-overflow, pumping well and reservoir, three deposit tanks provided with syphons and overflow, pumps for lifting sludge and cleaning tanks, sludge beds, two engines with pumps, boilers, and all completements for lifting the sewage, and all mixing apparatus, and pump for pure water supply.

The works serve well as model for towns similarly situated, and they practically show that and how a great deal can be done with the expenditure of comparatively little money.

WINDSOR.

The Windsor Sewage Works were designed by Messrs. Thomas and Charles Hawksley, and have been carried out in substantial and costly style; they well deserve a visit of inspection, as they show, like all Messrs. Hawksley's works, perfection in every detail. The sewage is carried from Windsor by means of an intercepting sewer, 4ft. 6in. in diameter, and about three miles in length, to the pumping well at the outfall works, and this sewer serves for all practical purposes as storm reservoir at the same time. From the pumping well sewage and chemicals mixed together are lifted and delivered into three deposit tanks, and from these the effluent is either discharged through an outfall chamber into the river, or it is turned upon filtering beds and finds its way thus into the Thames.

The effluent at Windsor is of a very fair quality, and there is no difficulty in disposing of the sludge, the whole of which is used on the land as manure. The Windsor sewage has been treated by me since the works were opened in October last, and they answer well the purpose for which they were intended.

The Sewage Works at Birkdale and Somerton will soon be finished, and there are several large towns which have definitely adopted my plans for outfall works, and my method of sewage disposal. Of those places I intend to give an account at some future occasion.

SEWAGE DISPOSAL AT WREXHAM.

By Lieut.-Col. Alfred S. Jones, V.C., Assoc. M. Inst. C.E.

In the course of former Conferences, and elsewhere, the details of my experience in dealing with the town sewage of Wrexham have been given to the public for six years, and it seems possible that the following preliminary remarks may not be out of place, as an introduction to my balance-sheet of the seventh year, ended 2nd Feb., 1879.

First, I feel very thankful that I have been able to carry my experiment so far, without interference from those more serious accidents which are apt to break the course of all human undertakings, and that I have lived with my family of six healthy children within some 250 feet of a sewage carrier, while Mr. Jackson, dairyman, residing in the centre of the farm, has been equally fortunate with another young family, so that our experience supports the conclusion, established in many other places, that the proper utilisation of town sewage need not cause a nuisance injurious to health.

But, in taking up the subject, I considered that its sanitary effects required little further proof, and I directed my attention mainly to the financial problem, regarding which public opinion was just then (1872) beginning to recoil from extravagant views of the profit to be derived from sewage, which had been set forth by various enthusiasts, and was then in danger of rushing to the other extreme, in viewing sewage as a source of inevitable and excessive loss.

If I have contributed in the smallest degree to check this recoil, and, acting like the natural force of gravity, have helped to bring the pendulum to rest in its true vertical position of equilibrium, midway between the extremes, I cannot have laboured in vain. But the knowledge that many engineers and others have been brought to recognise one fundamental error, which has marred the sewerage of nearly all our towns, forms my chief cause of satisfaction. That rough and ready plan of mixing up sewage with surface and subsoil water has indeed been fatal to the effective use of sewage, and this evil, intensified during several wet seasons, has had its influence upon my balance-sheet in a very unpleasant manner.

Hafod-y-Wern Farm.—Balance-sheet for the Year ended 2nd February, 1879.

1878.		£	s.	d.	1879.		£	s.	d.
Feb. 2.—To	outstanding debts	154	19	9½	Feb. 2.—By	receipts for the year ended this date	1,074	8	1
,,	valuation of live and dead stock	818	4	0	,,	sundry debtors	62	15	1½
,,	,, permanent improvements, viz., £807 6s. 4d., less £40 paid per last balance sheet to sinking fund	767	6	4	,,	valuation of live and dead stock	949	10	0
1879.					,,	,, permanent improvements	792	6	4
Feb. 2.—To	wages for year ended this date	446	11	6½					
,,	rent, rates, taxes, &c., do.	473	1	0					
,,	other payments, do.	98	18	0					
	Interest on capital, viz., 5 per on £1,800	90	0	0					
	Balance profit on year's farming*, by Lieut.-Col. Jones.	29	18	10½					
		£2,878	19	6½			£2,878	19	6½

It will be seen, from the above account, that I am compelled to postpone, to a more favourable season, the payment to sinking fund which has appeared in previous balance-sheets, because, after deducting 5 per cent. interest on capital, there remains but a very small margin of profit on the seventh year's farming.

Indeed, looking at this balance-sheet by itself, one might well feel discouraged. But I have long been convinced that no fair judgment as to the results of farming can ever be arrived at from any single year's accounts, where so much depends upon the season, and the nature of the stock on hand at the beginning and end of the period, together with their market prices.

But, at page 46 of the second edition of my pamphlet, I have indicated a safe and simple mode of lumping the accounts of several years, whereby, when every receipt and payment has been extracted from the cash-book, it is only necessary to add outstanding debts and valuations of the stock, &c., at the end of the period, to the total receipts, and to subtract from that sum the total payments; thus—

	£	s.	d.
Cash receipts of first five years, *vide* page 46 as above	7,245	2	10½
Cash receipts, 1877-8	1,188	4	8
Do. 1878-9	1,074	8	1
Outstanding debts, 2nd February, 1879	55	5	1½
Valuations—Stock ,, ,,	949	10	0
Do. Permanent improvements ,,	792	6	4
	£11,304	17	1

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* It should be noted that this is over and above any profit realised by Mr. Jackson, the dairyman, keeping his own cows and living upon this farm, paying for the keep of his cows, &c., such payments being accounted for in the gross receipts, &c., on the other side of the above account.

Carried forward	£11,304	17	1
Total produce in seven years, resulting from total payments as per other side	9,527	1	6½
Excess of results, over total payments producing those results, being gross profit of the seven years' business ..	£1,777	15	6½
	£	s.	d.
Deducting 10 per cent. for seven years, for interest and repayment of capital, this gross profit of	1,777	15	6½
Less 10 per cent. on £1,600 = 160 × seven years = ...	1,120	0	0
Leaving	£657	15	6½

As the net profit over 84 acres for three years, and 104 acres for four years (say an average of 95 acres for seven years), and £657 15s. 6½d. divided by 95 × 7 = 665, gives 19s. 9d. as the net average annual profit per acre.

	£	s.	d.
Cash payments, first five years	7,428	8	3½
Do. 1877-8	1,080	2	8½
Do. 1878-9	1,018	10	6½
	£9,527	1	6½

Having never been absent more than a week at a time during the last seven years, I am personally responsible for the record of the Hafod-y-Wern farm accounts, and when due allowance is made for my own deficiencies, and want of early agricultural training, as well as for the very high rent of the land, and excess of water mixed with the sewage, it will, probably, be concluded that the question, "Will a sewage farm pay?" may be answered in the affirmative; at any rate, it is my firm conviction that, given the right sort of land and undiluted sewage, a farmer may certainly pay a rent of £4 to £5 per imperial acre, and make a fair profit for his time and capital.

In my remarks, at page 75, of the proceedings at the last Conference, I described the commencement of experiments upon the drying of sewage sludge, and preparation of a useful general purpose artificial manure, by the subsequent mixing of a due proportion of bone meal and sulphate of ammonia with the dry poudrette, and I still hope that this compound will deserve its name of the "Farmer's Friend,"

While recognising the theory that a thorough scientific farmer may do better by analysing his soil, and applying exactly the right proportion of those elements of plant food, which by that means, and by previous observations he may judge to be wanting for the production of the particular crop he desires to grow (for in that way he might reduce the cost of transport and spreading of his manure to a minimum) my knowledge of human, and especially of farmer, nature leads me to believe that it will be long before our crops are generally grown upon exactly that principle, however desirable it may be to keep it fully in view as an object of agricultural education.

I can well remember the lessons I learnt as a boy, from an old landowner and farmer in Leicestershire, whose creed was, that "where there is muck there is money," and who treasured up his farmyard manure and anything he could make into compost, knowing that it would be equally efficaceous for grass, corn, and turnips. This gentleman and his successors were ready enough to see the value of Peruvian guano as it used to be, when first introduced into this country, good for all crops and soils, but he and they have hardly yet been educated to Mr. Lawes' pitch of perfection, which might enable them to apply with safety, and to buy without being cheated, nitrate of soda for one field, and the cheapest combination of phosphoric acid or potash required for another.

Manure makers in every district have recognised this natural demand of the farmer for a compound manure, which he may safely apply directly from the bags in which he receives it, without any of that careful mixture with sifted ashes, soil, salt, &c., which the highly educated farmer knows he must make with his sulphate of ammonia or nitrate of soda, to insure its even distribution, and they have traded on the farmers' ignorance by supplying him with special manures for grass, corn, potatoes, turnips, and mangold, differing little, if at all, except in name and price, but all containing more or less nitrogen and phosphoric acid, and weighted with a commission of 20s. or more per ton, for the benefit of the agents who attend every market, soliciting orders in keen competition with each other.

Having dried my sludge to a poudrette, very much resembling the basis of such compound manures, and worth by analysis about 30s. per ton. I applied to the best authorities to suggest an addition of phosphate of lime and nitrogen, which mixed with my base, would give a manure likely to take well with the farmer, as efficacious for all crops, and I felt that my neighbours would have confidence in my maintaining exactly the proportions once fixed

The "Farmer's Friend" consists of
1 cwt. sulphate of ammonia.
7 ,, fine raw bone meal.
12 ,, dried sewage sludge.

1 ton.

and buying my bone meal and sulphate at a distance, I can sell the compound with a fair profit at £6 10s. per ton in bags, or about £2 per ton cheaper than the best of the compound manures in the market. But, with a steady market, ensured for such a manure, it might be made at every town's sewage works as low as £5 per ton, by collecting and grinding the bones, and making sulphate from the liquor of the local gas works, all on the spot where the sludge is dried, and thus saving, not only the carriage, but the manufacturing profit upon each of the ingredients, which, for want of expensive plant, I have to import from a distance, although every town which produces sewage, will yield also, bones and ammoniacal liquor for sulphate, if people will take the trouble to collect those raw materials on the spot, and prepare them at the sewage works for admixture with the dried sludge.

Such a saving as some 40 per cent. on his present manure bill, which the difference between £5 and £8 10s. would afford, should be worth striving for, and the example of the Civil Service and Army and Navy Co-operative Stores, in dispensing with the convenience of retail shopkeepers calling for orders, and putting down goods on unlimited credit, may tempt farmers to send to the nearest town works with cash for their manure, instead of yielding, as they have done, too much to the persuasions of touting agents.

Farmers are partial to old friends, however, and not very ready to take up with new ones, so I must be patient, and shall not lay out the additional capital for bone meal machinery and sulphate making, until I see a steady demand for "Farmer's Friend" at the price of £6 10s., or something less, at which it pays me to prepare it with my present appliances; but the experience I have had in selling 172 tons last season, and a corresponding quantity so far during the present one, is sufficiently satisfactory, and the reduction of nearly £2 already offered to the farmer, ought to be a good move in the right direction.

There seems to be a sort of fatality attending those who take up the sewage question superficially, inclining them to exaggerate the value of sewage, and even that of the comparatively worthless sludge which they fancy can be turned into gold at a moment's notice, by the aid of a "Limited Company" with the stock exchange manipulation of its shares, and I regret that Mr. Kidd, the patentee of a drying machine I referred to at the last Conference, became shortly afterwards a victim to this sewage malady, and was soon discontented with the tentative policy which I had established, in my capacity as sole manager of the Wrexham Manure Company from its formation. He has since formed a limited company with which I have no connection, but which I understand is about to imitate, on a far bolder scale, at the neighbouring town of Oswestry, the experiment which I continue to carry on cautiously at Wrexham.

In buying Mr. Kidd out of the Wrexham Manure Company, as I was compelled to do by the access of this fever in June last, I acquired the right to use two of his machines anywhere free of patent rights; but having, while the negotiation was pending, procured a machine of totally different construction, though utilising the same valuable principle of bringing the substance to be dried into direct contact with the smoke and gases of combustion from the heat producing furnace, I have found the new machine quite satisfactory, and sufficient for all my work at present, so that I have not yet made any use of my right to work Mr. Kidd's patent since he ceased to be connected with my Wrexham Manure Company.

The machine I am now using is the invention of Mr. W. A. Gibbs, Gillwell-park, Essex, a gentleman who has devoted himself most patiently, for many years, to experiments in drying hay, corn, and a great variety of other articles.

I adopted Mr. Gibbs' machine with the double object of drying Italian rye-grass for hay, as well as for sludge drying, thus securing work for it throughout the year; and last autumn I made a stack four yards square of hay, put together just as it came out of the drying machine.

The process was as follows:—A load of green grass, preferably fresh from the scythe, but often sodden from lying in the swathe under rain, was drawn alongside of a chaff-cutter mounted on a platform over the feeding end of a long revolving iron cylinder, which constitutes the drying machine. A 2 h.-p. steam-engine turned this cylinder, a fan which drives the fire gases through it, an elevator to carry the dried hay on to the stack, and the chaff-cutter through which the green grass was passed in the first instance, and whence it dropped into the feeding hopper of the revolving drying cylinder.

The chopped hay thus produced contained from 25 to 30 per cent. of moisture, and to all appearance was fit for stacking in the ordinary way, but, from being chopped, the moisture from subsequent sweating had not the same chance of escape as ordinary long hay affords, and, consequently, the stack was spoiled by mould because it remained warm and damp for about two months, instead of going through the more rapid, and sometimes dangerous, heating of an ordinary haystack.

Italian rye-grass grown from sewage is so succulent and heavy a crop, that it requires more care and time to save it than ordinary hay grass; but I have made a stack of it every year with such success, that my own horses and cows live upon it through the winter, as a rule, and in our uncertain climate a drying machine is a great desideratum, for this reason, viz.: that there is no crop which can be produced to greater pecuniary profit on a sewage farm than Italian rye-grass, if even two out of the six annual cuttings can be sold green on the ground; and, therefore, it is an object to have enough land under this crop to supply the local demand for green fodder in a dry season, even at the sacrifice of great waste of grass at times, when this demand is slack, as it will be at all seasons of growth on ordinary pasture in the neighbourhood, because people will not buy when they have grass on their own fields.

It thus happens that if the expense of cutting and drying can be covered (about 15 shillings per ton of dried hay), any margin between that and the price of the worst hay remains for profit, quite enough to induce great efforts to attain perfection in the drying process, which I have endeavoured to explain.

I shall now pass on, with your permission, to notice experiments relating to town sewage, and the pumping of sewage to land not commanded by gravitation, experiments which are especially interesting to me, from their having arisen out of the acquaintance of the Mayor of Wrexham with my farm, and because the first application of his new pneumatic system is now in course of demonstration upon my land.

At one of the earliest of these Conferences, I threw out the idea that it would be well if engineers, in undertaking works of sewerage, would adopt more definite plans, founded upon such data as are used in laying on water supply to towns.

Excluding rain and subsoil water under the separate system, which has at last fought its way to the front, it is clear that the water supply of a street or a town, is as nearly as may be, the measure of the fouled water or sewage which requires removal from the same locality; and I suggested that engineers, who are careful to proportion the water-pipes and pressure to such quantities, might easily apply the same data to the size and fall of sewers, instead of making the latter three or four times as large as the corresponding water-pipes, and thus ensuring a very slow current and ample gas-holding space in pipes which convey the gas generating liquid, while they provide for the clean water pipes running always full.

In thus advocating the speedy removal of sewage, by pipes kept as nearly full and running as fast as possible, I thought only of applying the natural force of gravity; but Mr. Isaac Shone, an engineer from my own town, seized upon the idea, and extended to its utmost limit the reduction of gas-holding space, by providing for the constant movement of fresh sewage through a full pipe from the dwelling to the land. Imitating the head of water pressure in the water-mains by a corresponding pressure of condensed air, he pretends to cause a regular steady flow of fresh sewage along full pipes, from the several districts of a town to a sewage outfall, and would thus render any formation of sewer gas simply impossible throughout his system of sewerage. Those of us who have paid much attention to expedients for reducing and keeping sewer-gas out of houses would thus find our occupation gone, and must acknowledge that "prevention is better than cure."

Leaving Mr. Shone to explain, with diagrams, the very simple and inexpensive details of his system, I will only add that, in order to prove his assertions, he has set up, at his own expense, a complete example on my farm at Wrexham, which is open to the inspection of all interested parties, and that I have witnessed for the last two months the regular intermittent lifting of crude sewage, at the rate of about 4,000 gallons per hour, to a height of nearly 40 feet, with an effective air pressure of nearly 18 lbs. to the square inch.

I am persuaded that compressed air, *not as a motive power*, as it is usually regarded, but *as a means of transmitting power from place to place*, has not hitherto received the attention it deserves, because, in the absence of Mr. Shone's invention, compressed air has usually needed a cylinder and piston to produce effective work at its point of application, and has consequently been debited with the friction and mechanical defects of such executive engines, in comparisons of the expense of steam and compressed air, each doing so many units of work.

This loss of useful effect has led to the common belief that compressed air is a most expensive power; but as Mr. Shone's diagrams will show you, his column of compressed air is simply an agent for the transmission of a steam engine's or a water-wheel's motive power to great distances with exceedingly little loss, and for exerting the motive power directly upon the surface of the fluid to be lifted, without involving piston or any frictional loss by machinery of any kind, on the spot where the lift takes place, such as would be required for doing the same work in any other manner.

The expenditure of power, in the shape of air compressed to the required number of lbs. per square inch, is just the equivalent in volume of the fluid lifted; and as experiments in mines and tunnelling works have amply demonstrated that this pressure of air can be extended for several miles with very little loss, at low pressures, it is evident that in many cases the compression may be effected by water power at almost nominal cost.

No engineer, who has had to collect at one spot the sewage of a town built upon undulating ground, can fail to see what an advantage he might derive from lifts of 20 to 40 feet applied, just where required in the manhole of a street, by a distant water-wheel, turbine, or steam-engine, from which mains of compressed air would radiate to those several man-holes containing Shone's "ejector."

The inventor goes further than this, and claims in a flat place such as Southport or Llandudno, to push the sewage along a sealed pipe, laid two or three feet below the surface throughout the town, and, if necessary, uphill, to an elevated sewage farm, or into the sea against the tide. The pipe would thus be always full of fresh sewage, driven along at a rate of not less than three feet per second. And, in such a case as that supposed, whenever one of the "ejectors" becomes full, it turns on the compressed air, and empty itself by its automatic arrangement misplaced; it is evident that a volume of sewage, equal to the full contents of an "ejector," will be discharged at the outfall, each time that one of these ingenious contrivances turns on the compressed air.

The sanitary advantages of this system are very striking, because increased fall can be given to the house drains and district sewers, emptying into an "ejector," and the temporary backing up of sewage in those contributory sewers, while the inlet valve of the ejector is closed during ejection, would give a very effective flushing on the next intermittent filling of the "ejector." This system would also most effectually sever each district from the sewage or sewer-gas of the rest of the town, by a constantly renewed water seal of some feet in thickness, and the exhaust air being led into a gravitating sewer after each discharge would improve the sewer ventilation *pro tanto*.

I will not dwell further on this subject, except to remind any of my hearers who were present at the annual congress of the Sanitary Institute of Great Britain, held at Stafford in October last, that I there stated my belief that, if certain mechanical difficulties could be overcome in practice, the Stafford meeting would become conspicuous in the future, as that at which Mr. Shone's revolution in sewerage was first introduced to public notice. Since that time I have seen the new pneumatic system set to work with fewer hitches than are usually experienced with new inventions, in fact, I may say, with complete success, to the satisfaction of many experienced and practical engineers who have watched the trials from the first, and I would add that I never before knew crude sewage suffered to enter a pump without previous straining through a grating, but that all kinds of matter usually found in town sewage have freely passed through the ejector without causing any trouble with its valves.

[Mr. Isaac Shone, the Mayor of Wrexham, attended the Conference, but was unable to obtain an opportunity of explaining his Pneumatic Sewerage System. He will be glad to show the system in operation at Wrexham, to anyone interested in the subject.]

THE DOUBLE CHECK SYSTEM OF HOUSE DRAINAGE.

By Henry Masters.

Upon reviewing the various systems of house drainage that have been brought before the public during the past dozen years, I have been struck with the absence of simplicity in many of the schemes propounded. One school of sanitarians consider special-made traps essential. Another, the absolute necessity of mechanical contrivance for pumping up, or extracting the foul air from drains, though each agree that drain ventilation is necessary.

Nearly all the schemes put forward advocate up-currents of air by single pipes, and pumping terminations; some admitting air near the ground, and some not. If the multiplicity of special pipe terminations be evidence, down draft is a very formidable thing to contend with. In my scheme, I am a great friend to down draft, I advocate and encourage it in every possible manner, and the more I get of it the better. I therefore differ in this particular from other sanitarians.

In my early practice, as an architect and surveyor, the correct thing was to trap every closet, sink, and outlet; also, to put traps at the foot of every soil and rainwater pipe, and the over-flows of tanks, the great object being to hermetically seal, so far as possible, every drain and soil pipe; the latter was made tight at top and bottom, and the former at either end. The same principle of tight work was applied to our common sewers, and I regret that we have still advocates for sealing, both as regards the sewers of our towns, and also our private drains.

Upon applying my double-check system of house drainage, I always avoid using any specialty or mechanical contrivance. All the details required may be purchased at ordinary dealers in sanitary ware and ironmongers. I use, generally, the common form of trap, ordinary glazed ware pipes (sometimes with Sandford's joints), and stout cast-iron soil and air pipes, selecting only careful and well-proved men for doing the work. My experience having taught me that simplicity is the best engineering, and the less parts the better; I decidedly object to any mechanical valves or revolving terminations.

As an example of simplicity of house drainage, and as a system which could never get out of repair, although we have, upon referring to the past, but few examples left us of the sanitary arrangements of our mediæval forefathers, I cannot refrain from bringing before you one such example of a well-arranged and ventilated system of domestic drainage, as applied to the hospital of St. Cross, Hampshire.

The architect of St. Cross, in common with the forethought that governed our forefathers in the selection of suitable sites for their religious and domestic buildings, took care that abundance of water, and facilities for drainage, should be secured. In the case of St. Cross, the water from the River Itchin is higher above the hospital than below; advantage was taken of this circumstance to make a culvert from the higher part in the direction of the building, and in the garden was constructed an open pond, through which the water flowed, and was the source of the domestic supply. It then passed on and round the brethren's dwellings, and under a foot-bridge, constructed for the double purpose of communication with the garden, and for throwing over waste from the cooking department. The water passed on under several projecting wings of the building, in which were placed the closets, four in each wing, two up stairs and two down. In the domestic arrangements of St. Cross, each brother had a complete suite of apartments. They were provided with a sitting-room and a bed-room, and also a scullery, where they washed, and from the sculleries were approached closets, one to each dwelling in the wings referred to, and here we have a perfect system of ventilated drains and open soil pipes, the former an open channel by the river-water being diverted, and the latter a shaft, about a yard square, extending from a short distance of the running water to the seat, by which the soil passed directly into the water, air being freely admitted to the soil trunk, and passing out through the seats and open windows of the closets.

I admit that the system adopted by the Brethren at St. Cross would be hardly applicable to our modern views, but we can take a lesson from the works of these old men. Their sewers, as well as their soil-shafts were open from end to end, and they avoided the complication of traps and cowls.

Unfortunately, in our cities, we are driven by circumstances to use to some extent close drains, and I hardly think we are prepared to advocate open channels for our sewage, through the middle of our streets, or open shafts for our closets; and, without expressing any opinion what others have done with special traps and cowls, I will describe a scheme I have applied during many years of my architectural practice, and in every case have found it effective.

The scheme I advocate for house drainage I have designated "The Double Check System," because I apply a double trap and a double air-pipe, using three pipes altogether, branches from the closets inside pass through the external walls and join the soil-pipe, which is extended above the roof and clear of all windows, the curved termination of this pipe points in the direction of the house front. Where the drain passes out from the front of the house an air-pipe is connected; this also extends above the roof, the curved end pointing in the reverse direction to the soil-pipe termination.

Houses that are connected together are much more difficult to drain than when detached; my selected examples, as shown by the drawings exhibited, are from houses in rows. If the houses are detached, I invariably put all drains outside the walls, and cut off all waste pipes, I also ventilate all the drains as described.

The double check system, in its most simple form of application, consists of a pipe drain from the back to the front of the house, if in a row, or outside the house if detached; at the back of the house, it is joined to the vertical soil-pipe, to which are connected the w.c. pans. This soil pipe extends its full size above the roof, and has a curved termination, pointing from the house (say to the right). At a point of the pipe drain outside the front of the house is connected a large iron air pipe extending above the roof; this air pipe has also a curved termination, the same as upon the soil pipe extension, but it points in a reverse direction, or from the front of the house (say to the left) thus we have a U-shaped arrangement; an open pipe at the front of the house, with a left-hand curve, an open pipe at the back of the house with a right-hand curve, the lower ends of each pipe connected with the drain.

The foregoing explanations have reference to the house-drains proper, but unless accompanied by some arrangement for cutting off the public sewers from the house drains, the system would become a "public sewer ventilator," and to ventilate the public sewers at private expense, or to assist in establishing a current of sewer gas in the direction of the house would be alike opposed to my views. I have, therefore, arranged a double trap for this purpose.

There is no specialty in this trap. It is simply two common syphon traps (as known in the building trade by that name), connected together by a short junction pipe, to which is attached a large iron gas exit or escape pipe, extending above the house roof. The action of this double check sewer gas trap is as follows:—Upon such occasions as a pressure of gas present in the public sewers, capable of exerting sufficient force to pass a water trap, a portion of such gas will be forced into the house drain, and passing the first trap (which acts as a safety valve), it will meet with resistance at the second trap, but, meeting with no further hindrance, will pass up the large gas exit pipe, and so escape into the air above the house roof. Sewer gas, therefore, either by being forced through the water of the first syphon trap, or being absorbed by the trap water, is prevented from passing into the house drains by a barrier, viz., the second syphon trap, which in an occupied house, would be always charged with water. If pressure existed, it would be released as soon as the first trap is passed, because it would have a large pipe provided for its escape freely into the air, and above the roof.

The tops of all pipes are protected with terminations, the capacity of the air-ways being equal to the area of pipe. I object to any mechanical terminal, preferring only such contrivances that cannot get out of order, and that may be procured easily, and which will prevent birds making their nests in the pipes.

In order that any system of house drains be perfect, it is absolutely necessary that facilities should be given, so that any accumulation of impure air in the drain or soil-pipes should be made to periodically "move on" and finally be expelled. All house drains and soil pipes become somewhat foul in the course of time, and if I were to introduce an old soil-pipe into this room, you would, I am sure, object to be in its company. Many old soil-pipes have been found to be thickly lined with very disagreeable substances, giving off the most unpleasant scents, especially when in a damp state, and during hot, calm weather; and we all know the very unpleasant odour prevailing in many of our houses after the cooking of cabbage. These emanations should be got rid of as soon as possible.

In my experience of revolving cowls, which make one believe (during their revolutions) they are doing some good, I have found that at the time they are most required they are at a stand still, and act as obstructives, and when there is plenty of wind and no necessity for screwing, they revolve at a furious rate. This must, of necessity, be the case during winds and calms, and in the curved termination I apply to my system I labour under the same disadvantage. When the wind blows strongly from nearly every point of the compass, a strong current of air passes into one of my curved pipes through the drain and soil-pipe and out of the other, carrying with it any foul air that may be in the drain, but when there is a calm very little air is made to pass by natural currents. But, although I am anxious to take advantage of the passing currents of air, and they add to the value of my system by clearing the drains and pipes when the wind blows, I depend upon another power for obtaining the desired end.

In the present day, every closet is constructed so that it may be flushed by about two gallons of water; this quantity of water, if it were possible to be forced at once into the 4-inch soil-pipe, would form a solid piston of water, about a yard long, and would, in descending, push before it with considerable power the air in the pipes; and if the soil-pipe were 10 ft. long, 10 ft. of air would be displaced, and forced out of the open end of the pipe, at the same time, air would pass into the top of the soil-pipe extension, and follow the water-piston, so that during the time it was acting as a displacer of foul air, it would be filling the vacuum with fresh air; and, if I had not such an objection to mechanical valves, I could easily contrive one that would retain the yard of water in the soil-pipe, which, being released suddenly, would act with very great power, but as in practice I have found it is desirable to lay on the water for pan-flushing by a large pipe, say 1½-inch bore, taking care that the valve which allows the water to escape from the flush tank, and also the way into the closet-pan, be of equal capacity to the pipe, a good flush is procured, and the descent of water, passing down the soil-pipe, acting in a zigzag and spiral form, produces an effect similar to the solid water piston described, and it has the advantage of being more gradual in its action, and thereby displacing more foul air than though it acted suddenly. All open-top soil-pipes having no exit pipes, lose, to a large extent, this piston power for displacing foul air, and those having an opening near the ground (as in some systems) act as I have described, but with the disadvantage that, upon each occasion of the closet being used, a portion of foul air is forced out of such an opening, and it becomes in course of time very objectionable; for we all object to a disagreeable odour under our noses, and in the vicinity of our doors and windows. The double check system has the advantage of being free from the objections I have pointed out, the soil pipes and drains being open at either end, so that any foul air in them may be displaced, are easily acted upon, and I have found that a bucket of warm water thrown down the kitchen sink has caused a current of air to circulate through the pipes; and a leaky water tap, allowing a small quantity of water to pass down the drain constantly, has during the night, and at other times, caused a moderate flow of air in one direction: and also in the arrangement of pipes, when one pipe is at the back of the house, and the other at the front, should the sun shine upon one pipe, the heat produced, will cause a free circulation so long as one pipe is warmer than the other. Of course the various powers described do occasionally act one against the other, there may be times when the water piston would be forcing air in one direction, and the bucket of water in the other, but in practice, this has but little effect upon the successful working of the system. Upon examination, I have found the drain and soil pipes very free from foul gases.

Some Sanitarians advocate non-trapping, but I have a strong conviction of the usefulness of suitable traps for water-closets, baths, sinks, and lavatories.

The closet pans I prefer are of the wash-out type, with large flush pipes, thus avoiding D-traps and valves; and where practicable, I fix a simple form of grease and flush tank in a suitable position, so that the kitchen grease may be removed periodically, and buckets of water thrown in to flush the house drains at any time.

I have not attempted in my paper to bring before you the mode by which air and soil pipes, when in sight, should be treated architecturally, but have preferred to confine my paper to a simple description of the double check system, but I am quite alive to the fact, that the treatment of soil and air pipes should have some consideration from my professional brethren. There is no reason why they may not be successfully treated so as to harmonise with, rather than disgrace, the building with which they are associated.

Models showing the action of water thrown down a w.c. for displacing air. Action of air passing over the bent ends of pipes. Action of double check trap exhibited.

The principles I have endeavoured to establish are:—

1. That a mass of water thrown down a pipe, will force air before it, and cause air to follow it, and thereby a temporary circulation of air will take place; and if the pipes are of the form of the letter U, air will pass into one leg and out of the other.

2. That a slight current of air entering the bent ends of a U-shaped pipe, will cause air to circulate through such pipe.

3. That a flow of air through a water trap will pass through a second trap, unless there be means provided for its exit between the traps.

HOUSE DRAINAGE. — THE BANNER SYSTEM OF HOUSE SANITATION.

By E. G. Banner.

The object of the present Conference of the Society of Arts, we are informed, is to inquire into the merits of already known systems, rather than to discuss new or untried modes of dealing with this most important subject.

That house drainage, or house sanitation, as it is now pretty generally called, is a most important matter, no one now hesitates to admit. It is as fully admitted, notwithstanding the great advance that has been made, within the last few years, in the true knowledge of it, by some who have carefully studied the subject, that the community at large, including both the wealthy and educated classes, remain in almost entire ignorance of it, and so fall an easy prey to ignorant or inexperienced practitioners.

When we are authoritatively told that an immense number of deaths occur annually in the United Kingdom from preventible causes nothing more need be said in proof of its vast and daily increasing importance. No one, however high his or her station, should be above seeking for full information on the subject, however disagreeable even thinking of it may be, and anyone who, having given free and unbiassed consideration to it, and who feels he can add to the general store of knowledge, would fail in his duty to his fellows, if he omitted to respond to the invitation which this Society has again this year sent out; for among the many very important matters which constantly claim and receive the carfeul attention of the Society of Arts, it may be safely said there is not one of greater importance than that which forms the subject of the present Conference—the public health.

The subject, no doubt, is a very broad one, and has, therefore, of necessity, to be considered under various heads; at present it is proposed to inquire only as to the best means of obtaining and securing an ample supply of pure water and wholesome houses. These two branches are so dependent, the one on the other, that without we secure both we shall not obtain the benefits of either.

The remarks I have to offer will apply almost entirely to the latter branch; and, if allowed to do so, I will demonstrate the force of them with models, which I have had prepared for that purpose.

Up to within the last year or two, the invariable practice of sanitary engineers was to rely on a multiplicity of traps, with the aid of water, for keeping houses free of sewer-gas. Innumerable kinds of traps were made for the purpose—some of them very ingenious. Not one, however, was equal to the duty required of it; to overcome the defect two were often used, and sometimes more, with, however, this extraordinary result, the greater the number of the traps used the further the engineer or architect found himself from what he was striving so perseveringly to accomplish, viz., a house free from sewer or sewage-gas; and, in fact, the house generally became the worse in this respect in proportion as the number of the traps used was increased.

I am alluding to the ways in which it was, until recently, usual to deal with the house drain, and the soil-pipe proper. In order to lessen the danger, it was not unusual to put separate pipes to carry off bath and other less offensive wastes, and to deliver them outside the wall of the house, above an open trap having a grid over it, this trap itself having only the insecure water seal as a protection against the drain or sewer to which it led. Sometimes the soil-pipe proper was what was called "ventilated," and I will show you directly what kind of ventilation this really was—that, in fact, it was not ventilated at all.

First, let me show you how utterly unreliable any mere water seal is as a trap against sewer-gas entering a house from a drain or a sewer.

You are aware, of course, as water passes down or along a pipe or drain, that the sewer gas, of which both is usually full, is driven past such traps, sometimes outside the house, but most frequently into the lower rooms. To prevent this really great danger, by what is still called "relieving the pressure," when water, &c., passed into and down a soil-pipe, sanitarians carried the soil-pipe, full bore, to the roof, or a little above the top closet, often as high only as an upper bedroom window, and we find a caution against the latter practice in the latest and best works on sanitary engineering, by such authorities as Latham, Denton, and Eassie, as well as, in "Practical Hygiène," by the late Dr. Parkes; and I may mention, too, as an authority on this subject also, Mr. Rogers Field, for, though I believe he had not, until 1876, written any book upon the subject, what he has given since as, in his opinion, the best mode of dealing with house drainage, is substantially what he learnt of me during the Congress held at Brighton by the National Association for the Promotion of Social Science, in the autumn of 1875, when he did me the honour, on my invitation, of testing, in the severest way he could, the system which I had introduced by my Lever-trap of 1872, and my exhaust-cowl of 1874, and which, at the time he saw them, had been in operation—most successful operation—for a year or two, with the inlet which I had discovered was necessary for fresh air, to the foot of the soil-pipe.

The talented author of "Sanitary Arrangements for Dwellings" also told me, in 1875, that my system was new to him, as did also Mr. Ernest Turner. I think it right to mention these facts, because there has been an attempt made lately, for some purpose or other, to disparage the usefulness of cowls. It is pretty well known that I do not endorse that opinion. I consider, however, that the point, if it really is still to be disputed, ought to be fairly and properly determined in the interest of the public alone, and it, no doubt, is a matter which may properly be sidered on an occasion such as the present.

Before I proceed to show you what, only a very few years ago, was thought by the most advanced sanitarians to be a "ventilated" soil pipe, let me give you clear proof of the exhaust power of the cowl I introduced in 1874. In proof of the great power of these cowls I will take this curved one-inch tube, in which the friction surface is three times the superficial area, and you will see that, on a length of 60 feet, with a common pair of bellows, the exhaust power of the cowl is sufficient to suck out a lighted taper held at the other extreme end of the tube. Now, 60 feet is far more than the ordinary length of the soil pipe of a house, it is never less than four inches in diameter, it is generally placed not only straight but vertical, which alone it is said gives it a decided advantage over a similar tube placed horizontally, while the friction surface in a four-inch tube is relatively only one quarter what it is in a tube like this of one inch diameter.

Now I will show you what, until very lately was considered to be a ventilated soil pipe and cesspool. You thus see, in truth and in fact, that it was really not ventilated at all; and, being always, as it was, full of sewer gas when only so "ventilated," whenever water, &c., passed down the soil-pipe, there was the certainty of the said sewer gas being driven by it through the traps beneath the lower closets, or of its being drawn by the heat of the rooms, into the house. Another very dangerous consequence of such ventilation is, that the upper part of the trap, as well as the upper side of the branch pipe leading from the trap to the soil-pipe, soon, and often very soon, was eaten away by the sewer gas, and then, of course, there was a highway always for the sewage gas generated in the traps, soil-pipe, &c., to pass freely into the rooms at all times.

By the system which I have already said was originally introduced by me a very few years since, no such dangers can exist, as a current of fresh air is constantly passing up the soil-pipe, and another similar current, separate and distinct from that made to pass up the soil-pipe, is also made to pass through the house drain, thus affording, and I contend in the very best way, a double security against any sewer or sewage gas entering a house.

What is known as the water-carriage system will be admitted as the most convenient as well as the simplest, and, therefore, as the best for the promotion of public health.

Ventilation—I must emphasise the word, and say real ventilation—of all the pipes and appliances necessary for carrying out that system is now pretty generally known to be an indispensible desideratum. Since I first introduced the simple mode and means of effecting it, we have had numerous other spurious plans proposed, but I shall, perhaps, be excused for saying that in my humble opinion not one of them is as perfect as the original.

Proper arrangements are needed, both for the admission of fresh air to the drain and the soil pipe at proper points in each, as well as for its being drawn not only into but through them, and made to escape above the roof of the house instead of near the windows, as used to be generally the case.

It will scarcely be allowed to me to enter into the many minor details which are necessary to ensure the thorough efficiency of the system, which I claim the credit of having introduced. Permit me, briefly, to mention some important points. It is comparatively unimportant whether the drains pass under the house, and whether the soil pipe happens to be within or outside the walls of the house, and what position in it the closets happen to be; for if even they are in the middle of the house—as very often happens in London—with proper arrangements they, nevertheless, and generally without much expense, can be made perfectly safe.

As I have already shown, no mere water seal can be relied on in any trap, to prevent gas from the sewer entering a house, if the house drain and soil pipe are not ventilated as I have shown they can, and, as I venture still to think, they always should be.

We have hardly yet got a perfect closet, perhaps. The first trapless closet introduced, so far as I know was Pearson's; others have been brought out since, which do not surpass it; but a well-made and well-kept pan-closet, I continue to think—and they are the kind mostly used—will be found all that is necessary for comfort and perfect safety, provided no traps of any kind are put immediately below them. The system, however, which I am advocating is quite independent of any particular kind of closet, but I unhesitatingly assert that any closet having a perpetual trap below it, or forming a part of it, is a decidedly imperfect one. I am aware that what is called a "wash-out" closet is approved by some. My objection to it is the same as to the common hopper closet, viz., it really prevents thorough ventilation, and requires an extra supply of water to flush it properly.

A very strenuous endeavour has been made to disparage the system I am advocating, by asserting that cowls are not necessary, and that they are liable to become fixed; this, I beg to say when they are properly made and properly stayis as unusual as is the breaking of the mainspring of a watch. An endeavour has also, I am told, been persistently made to have it believed that the system is an expensive one to carry out, while, in truth, the very reverse is the fact; by its adoption much lighter lead pipes may be used with perfect safety, extra pipes for the waste from baths and sinks are rendered quite unnecessary. Iron pipes may be used instead of lead, and the same pipes, of whatever material, may be used, not only for soil and bath wastes, but for rain water also, and as there is never any sewer or sewage gas in any of the pipes, the portions of them needed for ventilation only, may be of zinc instead of lead, as is necessary under the old plan. As confirmatory of this, I may mention that, in two recent instances the cost of carrying out the system, as compared with the estimates for what was proposed to be done at each on the old plan, was actually very little more than one-half.

This drawing shows the lever trap and its arrangement as introduced by me in 1872, and exhibited at the last International Exhibition in 1874. In this case the fresh air is brought to the foot of the soil-pipe by means of the rain-water pipe. It would be impossible of course to show all the many different ways of bringing fresh air there. The mode of doing it is a matter of perfect indifference so long as it is allowed, by any proper arrangement, to get there.

Some gentlemen, believe that fresh air, of its own accord, will go on a perpetual voyage of discovery down one pipe and up another, for the purpose, I suppose, of hunting out any sewer gas there may be in either. Another gentleman has lately made the further discovery, important, if it be true, that the said fresh air hunts perpetually up an open pipe during the day, and down it during the night. All I will say is, I do not agree with the learned advocates of either doctrine, and that to overcome the opposite belief I introduced the cowl I have shown you the power of, and of which this is a section. This cowl, as well as the lever trap, and its arrangement, was exhibited at the Sanitary Conference, at Glasgow, in 1874, and in proof of its excellence, I may say it has since been imitated by many, and by some, as I think, unscrupulously so.

An eminent medical man told me the other day that if he were obliged to dispense with one of two of the most important things known in his judgment, viz., medicine and pure air, he would do without the first—throw physic to the dogs in fact. You will probably agree with me in thinking this a strong testimony in favour of wholesome houses, and I trust that, now there is really reasonable ground for hope that the death-rate, ere very long, will be reduced from 34 per 1,000, in some towns, to 17 per 1,000 throughout the whole kingdom, and that the average duration of life, instead of being, as at present, 49, will be raised to, say, 60, apart from the probable great lessening of the actual death-rate, what an immense diminution of disease and sickness do such hoped-for results point to, nevertheless, in their honour and praise be it said, there are in no class or profession in the kingdom, more sincere, or more earnest advocates than medical men for unpolluted pure water. My friend, Dr. Richardson, stands out prominently now among the crowd in advocating this and a sufficient supply also of really pure air in wholesome houses.

Sewers.—I hope I shall be excused for saying that I don't think we have yet arrived at the best way of dealing with them, though they are truly a place of filth, and must, to a great extent, remain so. The present great inconvenience and danger which they occasion, might, I am persuaded, be very greatly diminished if not altogether avoided. We are told it is a great mistake not to ventilate them, but the means at present taken to accomplish this is so very objectionable, that in many places we see the plan most strenuously opposed. The plan pretty generally adopted, where the need of ventilation is admitted, is to make openings for the purpose through gratings in the middle of the street down to the sewer: these gratings, however, are rarely large enough and numerous enough to be of any effect for good, while they often do an immense amount of mischief. I will take the facts as will be admitted as existing within a radius of a mile or half a mile of this spot. The sewers are very large, I suppose at least 10 feet diameter. Between Adam-street and St. James's-street, a distance of about 1,350 yards, I find there are four gratings, such as I have mentioned, in that length of sewer. When the gratings are not stopped up, which in fact they generally are with dirt, there is one grating to every 1,000 feet of sewers; each grating affords about 50 inches of air space, while the cubic inches of air space each is expected to ventilate is about 200,000,000. Clearly, then, such openings cannot be of any effect for good, while at times what escapes may destroy life. Sometimes gratings are put under gateways, and very generally at crossings; in the latter case, I suppose, because such points are the junction of sewers as well as streets, and it is thought that at such points they serve to ventilate the sewers under all the streets more effectually, while really they do next to absolutely nothing for ventilating but a few feet of only one. If an opening exist in an unventilated air pipe, we know how dangerous as well as offensive that is; these gratings, opening into sewers, are scarcely less offensive, and serve, I verily believe, no really useful purpose. In Paris openings into the sewers are at the sides of the roadway, which, I think, a better plan than that adopted in London, but with other arrangements for delivering the waste from houses into a properly ventilated drain with one delivery from the latter into the sewer, I incline to think that gratings opening into the sewers, might be almost entirely dispensed with, and the constant ripping up of the street avoided.

I am aware that some objection at present is taken to a single drain being made to serve for even two houses, but by the plan I am about to suggest this objection would not arise. I think there is, as yet, no possibility of really ventilating a large sewer. I am certain it is quite easy to perfectly ventilate a large drain, a drain large enough to serve for 50 or 100 houses. The suggestion I have to offer is, that such an intercepting drain, of say about 12 in. diameter, might be made to run parallel with the sewer, with but one delivery from it into the sewer, which could easily be trapped, each house could have its own drain as now, but instead of being led directly into the unventilated sewer, should deliver into an intercepting ventilated drain, while the soil-pipe, the foulest pipe within each house, could easily be separately and most effectually ventilated also. Thus, I feel quite certain, all danger from sewer drains and soil-pipes would be done away with.

The intercepting drain should be placed under the control of some duly constituted authority in each parish or district, which would be responsible for its being kept in proper order, both as regards flushing and ventilating; and it may even be found practicable to collect the solid part of the most impure matter at each delivery into the sewer, deodorise it there, and remove it periodically to where it would be useful as manure, instead of, as now, being made to pass into streams, rendering them unfit for use.

CINDER-SIFTING ASH-CLOSETS.

By I. Conyers Morrell.

This system, which I invented some years ago, is now so well known throughout the country, that it is scarcely necessary to describe it. To those, however, who may not be acquainted with it, the following brief description will convey some idea of its value.

It is the only known system which is capable of utilising for sanitary and economical purposes the waste material which is found at every house. This material, under the old system, is consigned to what is known as a midden, or ash-pit, and is mainly composed of ashes, three-fourths of which are, on examination, found to be cinders, and the remainder fine ash-dust. This latter has been shown by Mr. Watts, in his "Dictionary of Chemistry," and by Dr. Stockhardt, in his "Chemistry of Agriculture," to be of great value, on the one hand, as a deodorant and absorbant; and, on the other, for agricultural purposes as a manure.

If any person will take an ordinary hand-riddle of fine mesh, and separate the cinders from the dust, and scatter the latter with a hand-scoop over the night soil of a closet, he will find that it keeps down all smell, and so prevents the offensive and injurious effects of human excrement. He need scarcely be told to put the sifted cinders on to the fire, and utilise them as fuel. But the operation of sifting cinders in this manner is so laborious, irksome, and uncleanly, that it is not likely to be carried out by any but those who are keenly sensitive on the observance of sanitary laws, and as these are found as yet, even after years of lecturing, to be a very small minority, we cannot rely upon the labour being voluntarily performed by many. Hence the invention of this cinder-sifting ash-closet, which is designed so that by a self-acting arrangement the cinders are sifted, and a dose of the fine ash-dust is scattered over the soil on each use of the closet. The ashes, as they come from the house fire-grate, are merely thrown through a hole in the wall, and find their way on to a sloping screener attached to the rear of the closet. By the pressure upon the seat, on use, this screener receives a motion by which the cinders roll down its incline, and fall into a space, where they are ready to collect for re-burning; the ash-dust falls through the sieve into a hopper, and [illegible]ance to a scoop which, on the person leaving the seat, delivers a dose of this dust on to the s immediately below the seat. The most rece improvements have been to secure all the abov being done by one moving part in the who arrangement, so that the simplicity of the applian is perfect, and is such that nothing less tha absolute wilful damage can put it out of orde The receptacle for the soil may be either a movabl pan or a fixed vault. If the pan is used, which the present time is most general, its removal tak place at weekly intervals. If the vault is used, i contents may be collected, without the m entering the vault, and carried away at monthl intervals. Where a regular system of collecti can be relied upon, perhaps the movable pai the best. This is held to be so by medical autho ties at the present day. For some reasons I sho not, however, be surprised to see the movab pail give place to the fixed vault, as for reason I cannot help thinking that the va would prove the most economical in collec Over three thousand of these closets in use in the Pendleton district of Salford, wh the movable pail is the receptacle. The prac there is to carry the full pail away, and repl it by a clean one. The full pails are convey a specially constructed cart to the corpora manure depôt, where the contents undergo a tre ment which consolidates them into a val manure that meets with a ready sale. At t depôt, arrangements also are provided for util the garbage and other refuse which are brou to it from the dwellings in a separate recep For my own part, I must confess that I sh prefer to see the manure offered to the farm its crude state, just as it leaves the soil recept This may, however, be difficult where the syst not universal in the district, as in such case p vision has to be made for dealing with the n collected from the old system of closets as we

It will be understood that whether a mova pail is used, or a fixed vault, under this sy the contents will be an equal mixture of soi dry-ash, and that, accordingly, the refuse is m or less a dry inoffensive mass of valuable ma in appearance resembling dark mould, and consistency which renders its removal a matter even if the vault is used. The absen deodorant and absorbant renders the recep during use most offensive, and so I can unders why the tub system is condemned by The contents are always in a slushy state besides being injurious during use, are difficul remove, hence the complaints we hear of the removal of the tubs to the manure d complaints which cannot possibly arise wher ash-closet system is properly carried ou believe that medical authorities advocate th system, because the contents are by it car bodily away, but it is difficult to understand some of these leaders in the van of sanitary provement can reconcile themselves to the ness and offensiveness of a tub of human remaining exposed, as it does, during a least seven days. I can only explain this by posing that the advocates of the tub, pure simple, are not acquainted with the fact of being a better system.

The advantages of the cinder-sifting ash-clo may be enumerated as follows:—

It costs no more, in its application to new premises, than the old midden system. It is perfect as a sanitary improvement. It economises fuel. It makes a valuable manure of that which is comparatively valueless under any other system. It reduces the cost of removing refuse, inasmuch as it leaves the greatest portion of the bulk on the premises in the form of cinders. It prevents the injury of land by covering it with a layer of cinders whenever night soil from middens is used for manure. It can supplement the ashes with any other dry material, such as dried earth, if at times it is desired to do so. It requires no extra attention. It cannot get out of order. It is applicable to any premises, and is equally suited to the mansion and the cottage, to schools and public institutions, to all of which it is extensively applied. It prevents the pollution of well waters. The closets are constructed in portable and skeleton forms, and are supplied only by the Sanitary Appliance Company, Limited, of Salford.

The following report of a deputation from a neighbouring town, who visited Pendleton to see the system in operation, should suffice to satisfy sanitary reformers that they may find in it the much-desired remedy for the evils common to the old midden and cesspool, without incurring the dangers that follow from the adoption of what is known as the tub system, or from the adoption of the water-closet system:—

> "They were first shown the 'Morrell' closets. These are really *pail* closets, with the addition of a cinder-sifter, so adapted, that by mechanical contrivance, a certain amount of fine ash is thrown into the pail every time the closet seat is relieved from pressure. The fine ash absorbs the urine and gases in its pores, and becomes more or less intimately mixed with the solid excreta. By this adaptation, the contents of the pail are not in that slushy condition observed in all cases where the pail receives only the human solid and liquid discharges, and the first stage in the preparation of a good, useful manure is thus done automatically.
>
> "These closets were particularly free from smell, and were very neat and clean. Salford has tried the simple pail, but has now discarded its use in favour of Morrell's improvement of it.
>
> "Every new house has its own separate closet, and old houses are compelled to have, at least, one closet to two dwellings. The pails are replaced at least once a-week, and conveyed in a covered van in daytime to the depôt at Salford-bridge. Here, one by one, they are emptied into an iron mixing trough, more fine ash thrown in along with a small quantity of sulphate of lime, and in a few minutes is discharged from the trough a dry, portable manure, in the course of a few hours quite free from smell, and sold at 12s. 6d. per ton. The coarse ash and clinker are ground in a mortar mill with sand and lime, and form an excellent mortar, easily saleable at 5s. 6d. per ton. The works are of very unpretentious character, the machinery simple, yet efficient, and the offensiveness as small as possible."

SEWAGE IRRIGATION IN PARIS.

By W. Allen Sturge, M.D.,

Assistant-Physician to the Royal Free Hospital.

During the last few years when sanitary science has been advancing at so rapid a pace in England, a similar movement has been going on in France, It is true that the French have, in some instances, been later than ourselves in introducing much-needed reforms; but, having once devoted their attention to a subject, the system of centralisation, which is so marked a feature of government in France, has enabled them to bring more power to bear upon the solution of great practical questions than is generally possible in England. The question of the disposal of sewage is a good example of the difference between the two countries. This subject has been a prominent one in England for a good many years. A large number of methods have been tried in different towns, with a view to avoiding pollution of air or of water, and most of these plans have been abandoned, either on account of their great expense, or on account of their failure to accomplish the object which they were intended to fulfil. Finally, after many years of experimentation, we seem to be solving the problem by establishing sewage farms, and the efforts of sanitary reformers are becoming more and more concentrated upon this mode of disposal of sewage, in the endeavour to bring it to perfection.

In France, on the other hand, the experimentation in this direction has been conducted on a much smaller scale; but, having been once aroused to the necessity for action, the authorities have profited by the experience gained in England; have decided in favour of devoting their energies to sewage irrigation; and have made one of their first attempts at Paris itself. Thus, whilst, in England, we shall have been the first to adopt sewage irrigation in a variety of localities, and under very different conditions, the French will have been the first to make use of this method for the disposal of the sewage of a town of the largest size.

The history of the introduction of sewage irrigation into France is briefly as follows:—Since the year 1832, a main drainage system on a large scale has been gradually perfected in Paris. Up to that time, numerous drains opened directly into the Seine, with the result that the river, in its course through the town, became greatly polluted. Under the new system of drainage, the sewage has been collected into one great channel, and carried to Clichy, a few miles below Paris, where it is turned into the river. As a consequence of this improvement, the Seine is purified, so far as the town of Paris is concerned; but for many miles below the outlet of the great sewer its condition has become even worse than before, and the numerous towns and villages on its banks, for a considerable distance, have suffered from all the evils arising from the presence of a polluted stream. It was to remedy this evil that the proposal was made, in 1864, by M. Mille, an eminent French engineer, to pour the sewage on to the land, and to purify the water by this means.

The problem presented to the French engineers differed from that which is met with in most English towns, in the fact that at Paris a very small proportion of solid excreta finds its way into the sewers. The solid excreta are for the most part received into well-constructed cesspools, which are emptied at intervals, and their contents converted into manure, and thus the quantity of organic matter in each cubic yard of sewer-water is considerably reduced, and the material to be dealt with is consequently more dilute than is the case in England.

The proposition made by M. Mille, was to convey the dilute sewage on to some barren, sandy land in the commune of Gennevilliers, within a short distance of the outlet of the sewer, to pour as much of it on to the land as the soil was capable of receiving, and gradually to extend the area thus irrigated, until the whole of the sewage was so disposed of. Operations were begun in 1869 by pumping a few thousand cubic yards of water on to about 17 acres of land, and, though the works were stopped for a time by the Franco-German war, the progress has been steady up to the present time, when about 1,000 acres of sewage-irrigated land are under cultivation. This area is found to be sufficient to purify about one-fifth of all the sewage of Paris; and a plan has been drawn up, and is likely to be shortly carried into execution, for providing the land requisite for the epuration of the remaining four-fifths. There still remain rather more than 1,000 acres in the commune of Gennevilliers, which it is intended to bring under irrigation; and to provide the remaining 3,000 acres, it is in contemplation to pump the sewage through a conduit some miles in length, on to an estate containing about 3,500 acres lying to the north of the forest of St. Germain. This land, which is State property, consists of sandy, unproductive soil, and is at present for the most part allowed to lie fallow. In addition, it is hoped that land in the communes bordering upon Gennevilliers, and lands lying in the neighbourhood of the main conduit to St. Germain may be gradually added to that already under irrigation.

There are certain differences between the French method of procedure and that followed in most English towns, where sewage irrigation has been introduced. The first of these is that, in Paris, the town has not bought or rented any one farm for the purpose of irrigation, and with a view to carrying on its own farming operations. On the contrary, the authorities have aimed at inducing independent cultivators to take the sewage for themselves. The few acres with which the experiment was begun were, it is true, bought by the town; but even here the operations were not begun until a number of peasants had agreed to till the land on their own account. Since that time, extension of the area under irrigation has been almost entirely effected by the offers of neighbouring proprietors to take sewage.

The estate at St. Germain, which has been selected for sewage purposes, will, however, be solely in the hands of the town authorities, who will themselves conduct the farming operations. By having a large estate in their own power, their position will be strengthened, because they will then be able to supply to independent cultivators just such quantity of sewage as they may require, all that is left being carried to their own land at St. Germain; the value of the irrigation will consequently become enhanced, and the demand for it increased. As the value of the sewage becomes appreciated, it is expected that the town authorities will be in a position to ask a fair price for what they supply, and they will thus obtain some return on the money expended over the works.

A second distinction between the French and English methods of irrigation is that at Gennevilliers, in consequence of the sewage being voluntarily taken by a number of proprietors, the land under irrigation is scattered somewhat widely over a considerable area instead of lying all within one boundary fence. The thousand acres are dispersed over an area of nearly three times that extent, strips of non-irrigated land lying between the irrigated fields, a sub-division which is an advantage from the sanitary point of view.

A third distinction is, that in France the epuration of the sewage is looked upon as only a first step towards its complete utilisation. The essential principle of the plan adopted at Paris is that it admits of indefinite extension. In English towns, where a sewage farm is rented by the municipality, the farm stands out by itself as something peculiar from the surrounding farms; there is often a great prejudice against it in the minds of neighbouring proprietors, and, I believe, it very rarely occurs that sewage is carried to other land than that comprised in the farm. This policy of isolation is one which it has, doubtless, been very difficult to avoid, but it is one which brings many evils in its wake. One of the results due to it is that there is little chance of doing more than epurate the sewage. It is well-known that land will absorb and purify a vastly greater quantity of sewage than can be used up by the crops growing upon it. In acquiring a sewage farm, the authorities of towns, with a view to keeping down initial expenses, base their calculations of the amount of land required upon the capacity of land to epurate, rather than upon the capacity of crops to utilise sewage. But it has hitherto been found impossible to pour very large quantities of sewage over lands without the production of more or less scum on the surface, which is difficult to get rid of, and which tends to give a show of reason to the popular outcry against sewage farms on the ground of their unhealthiness. Whatever disagreeable effects may arise from the presence of a sewage farm in the neighbourhood, can be traced to the presence of this scum and of stagnant sewage here and there. This difficulty would be greatly diminished if the sewage could be spread over so wide an area that only such small quantities would be supplied to each acre of ground as would, in the ordinary course of events, constitute the amount of manure requisite to obtain the largest possible crop that the land was capable of producing. Under the system which at present prevails in connection with English sewage farms, it will be almost impossible to bring about this much desired result; instead of a gradual extension of the irrigation works year by year, until the sewage is more generally utilised by the farmers in the neighbourhood of our towns, and bought by them only in such quantities as they may desire, we shall continue to have the one little plot of ground groaning under the rich fare with which it is supplied, and tending to keep up the prejudice already existing against it by the exhalation of effluvia which it will be impossible altogether to avoid.

As I have already said, the system adopted at Paris admits of almost indefinite extension. The sewage being taken by independent proprietors, the rise in the value of the land resulting from the irrigation is evident to everyone. Fresh leases of land recently brought under irrigation, are frequently being drawn up, the rent under the new leases being generally three, four, and even five times as much as that obtained before irrigation was introduced. This rise in price is by far the best argument with which to overcome ignorant prejudices; and thus it happens that one proprietor after another begs to have his land included in the network of conduits. It is easy to see what will be the result of this system. For the complete epuration of the Paris sewage, 5,000 acres of land will be required; for its complete utilisation, not less than 150,000 would be necessary. The saturation of 5,000 acres must inevitably be attended by some disagreeable consequences, the simple manuring of 150,000 could be attended by none. The acquisition of even 5,000 acres by the town authorities would be no easy matter; the supply of the wants of the farmers over 150,000 acres is merely a question of ordinary commerce; and now that the enormous value of sewage as manure is recognised and proved beyond a doubt by the great increase in the value of irrigated land, it can be only a question of time when an area nearly or quite as large as this is irrigated. Already an offer to take sewage to manure 9,000 acres has been made by the mayor of Méry-sur-Oise, a town lying a few miles to the north-west of Paris, and plans have also been drawn up for the formation of secondary conduits in connection with the great main conduit that is to carry the sewage to St. Germain. These secondary conduits will convey the sewage to various tracts of country in the neighbourhood as the demand arises for it.

At present the whole question of sewage irrigation is in an early stage of development, and epuration only is being attained. The financial results are already almost beyond expectation, but the inevitable results of sewage saturation have followed, viz., the presence of effluvia and the consequent outcry amongst the inhabitants of the district. Great complaints have been made that since the introduction of the irrigation, ague has become far more common than it was before, and that more deaths occur from diarrhœa and dysentery. It appears to be pretty certain that ague has increased at Gennevilliers of late years, but other causes have concurred with the establishment of irrigation in producing this result. Chief amongst them is a rise in the level of subterranean water, owing to the construction of a weir a few miles below Paris, which raised the level of the Seine between three and four feet, and thus caused an inundation of the cellars of the houses. The weir was finished just before the irrigations were begun, and if not the sole cause of the production of ague, it has, at any rate, greatly aided the irrigation in bringing about the increased frequency of this disease.

It is difficult to get at the real truth about the increase of diarrhœa. Most of the doctors of the neighbourhood assert that there has been a considerable increase; but Dr. Proust, who drew up a report upon the sanitary condition of Gennevilliers, attached but little weight to the evidence they brought forward. Whether, however, there be or be not a diminution in the healthiness of the neighbourhood, as the result of the saturation with sewage, which is at present going on at Gennevilliers, is a matter of only temporary importance; because, as the system become extended, and the amount of sewage distributed to each acre is greatly lessened, these evils will disappear. In England, on the contrary, the question is one of very great importance, because of the tendency which now prevails to establish permanent depôts for sewage saturation, and it is one which will doubtless attract the attention it deserves. Its further discussion I leave to those who are intimately acquainted with the working of English sewage farms.

THE VENTILATION OF SEWERS.

By John G. Winton.

The furnace system for the ventilation of coal mines has now become obsolete. The plan was a sluggish one, depending on the rarefaction of the air in the furnace or upcast shaft, which was so arranged with those intricate passages in the depths of the earth that, as the rarefied air ascended, another or downcast shaft supplied fresh air to the workings. The suction fan now takes the place of the furnace system. In some instances air is discharged and supplied by these fans at the rate of 100,000 cubic feet and upwards per minute.

Suction fans have been condemned by some authorities as inapplicable for the ventilation of our main-drainage systems. I think differently, that the main-drainage systems of Great Britain have been constructed in ignorance as regards ventilation. Our forefathers, no doubt, did not experience the want of proper ventilation and dilution of sewer gas, which now exists in densely-populated cities. Modern works have been constructed, ventilating shafts have been adopted, forming upcast and downcast, according to the locality, nature has been coaxed to aërate these foul receptacles, the sluggish gases have been purified by the charcoal process, and the noxious vapours have been trapped from our dwellings; yet, with all these precautions, very little has been done to create an in-draught into our main sewers dispersing the vapours from the subways far overhead.

In the first instance, I consider that the sewerage works of towns should be so planned that the low-lying districts are kept separate, as far as practicable, from those of the higher districts; that each district should have a separate sewer, carrying away the sewage and rainfall from that district alone, they should debouch into a main common to all, and should be arranged with large syphon bends, so that the sewer gas of one district may not flow into that of another district, thus I may be able to deal most effectually with the sewer gas. With such an arrangement, I propose drawing the gases out of each district, discharging them into the main common to all, and which eventually would be discharged at the outfall, or made to pass up a chimney, and be dispersed far over head.

Secondly, that all the existing water-carriage plans for the removal of refuse are defective, in the absence of an abundant supply of flushing water directly applied to the main drainage system. I have advocated pumping up sea-water for this purpose for sea-coast towns, and, indeed, for all towns where it could be cheaply and conveniently applied. I consider that, by the application of sea-water, the refuse would be pickled, and would find its way seaward before decomposition took place, and noxious gases were evolved. In all other towns the fresh water supply should be sufficient to meet ordinary requirements, as likewise for periodical or continuous flushing. In the application I have simply considered it necessary to flush the house pipes; and when these tributaries are properly flushed, the mains will likewise be so.

If it is once ceded that continuous flushing is needed for the present system, I consider that a separate system, independent of rainfall, is preferable for the removal of refuse and the effluent water from our dwellings. We should be able to dispense with gullies, and, as there would not be so many air-holes, the gases would be more effectually dealt with. However, there can be no objection to carry away the rainfall, discharging it into the large main already mentioned, which finally terminates at the outfall.

The small jets of water for flushing the pipes leading from the houses need not be more than ½ inch in diameter; the water should be made to spread, striking against the side of the pipe, thus tending to prevent in-draught, and placed in such a position as not to be affected with refuse. For sake of illustration, 4,000 of these jets would represent an area of 784 square inches, or a diameter of nearly 31½ inches; so, with the water delivered under a moderate pressure, as from ordinary cisterns, these small tributaries would eventually create a great rush of flushing water in the mains, the delivery being carefully calculated to suit the requirements.

In some recent examples for the ventilation of sewers, open gratings have been fitted in the middle of the roadways, in connection with shafts leading from the top of the main sewers. Many towns have such an arrangement. These, no doubt, allow the gases to flow out of the mains, more especially when the sewer gases are compressed by a sudden flow of water. In warm weather, with a minimum flow of water through the sewers, the gases rise very sluggishly, and we know the exhalations are very offensive. The "sun" is the furnace, as it were (of the plan adopted by the early miner), and the sewers being of lower temperature than the atmosphere, the cold air in the sewers rises through the open gratings; hence the various systems for deodorisising the gases by the charcoal process. In the winter months, our houses act as the furnaces; and as we try to make them as snug as possible, by reducing all in-draught through window fittings and doorways to the minimum, the open gratings, fitted to the main sewers, then act as feeders, sweeping a cold current of air through the sewers, which carries the foul gases along, and eventually rush through faulty fittings, into our comparatively warm dwellings. This must take place at all seasons of the year, and more especially during the night, when we cannot open our windows for ventilation, and when our rooms are at a higher temperature than the atmosphere. However, the more the sewers are properly aerated, reducing the in-draughts into our dwellings, from these noxious receptacles at all seasons of the year, the more healthful will our habitations become. So we are forced to condemn the plain "Roman" system, and advocate the suction fan method adopted by the modern miner.

The furnace system, for promoting ventilation, we all know to be a very expensive plan, unless we can utilise, as in large manufacturing districts, the numerous furnaces under steam boilers. This plan has, no doubt, certain advantages in being able to deodorise the gases, by passing them through the furnace, and then up tall chimneys, where the purified vapours would be wafted away into infinite space.

Next comes the suction fan, driven by the steam-engine. Now, we have a furnace, and at the same time we create a powerful current of air passing into, and drawn out of, the sewers, and then through the furnace and up the chimney to the clouds.

With fans propelled by wind we have a power uncertain and capricious. However, we consider Archimedean screw ventilators could be applied with a measure of success in many small villages where economy may be a desideratum. They are very sensitive; the least wind will cause them to revolve, and with such an apparatus placed on the top of a high chimney, the revolving wheel being six feet in diameter, we should have an engine of considerable power. These machines are fitted with spiral screw blades for creating an upward current. At times the action is feeble; the gases, however, would be kept in motion. In high winds the revolutions are considerable, and the gases would be screwed out of the sewers more rapidly, and instantly dispersed. Gas engines may be used for driving the fan, as some authorities may object to steam-engines and smoke chimneys studded over large and fashionable localities; but when we consider that science has rendered those shafts smokeless, the engine becomes a matter of convenience, and a good gas-engine of moderate power requires less skill on the part of the attendant.

Lastly, we have to consider the turbine or water engine for driving the fan. I have shown that, for the water-carriage system for the removal of refuse, more flushing water becomes imperative, and we propose taking advantage of the effluent water flowing from the turbine to effect a thorough cleansing of our underground netways. And, to satisfy the most fastidious, I propose drawing the gases through an inclosed bed of charcoal of sufficient capacity to suit the requirements.

I will now draw attention to these suction fans. A fan driven by an engine of 20 horse-power discharges 25,000 cubic feet per minute, the suction pipe being 30 inches in diameter, one mile of such a pipe contains 25,872 cubic feet, or a little more than the above fan delivers per minute. The mileage per hour drawn through this 30-inch pipe will be 58, in round numbers, and in the 24 hours 1,392 miles of air are drawn through this pipe of 30 inches in diameter, while the total quantity of air expelled by the machine is 36,000,000 cubic feet in the 24 hours, or, in other words, thirty-six millions of cubic feet would be drawn out of a certain sewerage area, and pure air would instantly fill up the void, pouring into the sewers through existing apertures, or properly constructed inlets. To place these fans in immediate connection with the sewers is impracticable. As the numerous gully holes would act as feeders, and the exhaustive power, at a short distance, would become inoperative, we must lay down a system of piping, so that the sewers may be attacked, and the gases gently drawn out over a large area. Were we to create a sudden rush of air at one part of the sewerage system, even although with no gully holes, we consider the water traps in the house arrangements would be unsealed, and, as we have already stated, the exhaustive power would be limited.

For sake of illustration, I will take a straight length of piping, commencing with 30 inches diameter at the fan. This line of piping should be graduated to a small diameter at the extreme end, of, say, one-sixth of the area, or 12¼ inches diameter, the end of the pipe being fitted with a blind flange. This being the main suction pipe, branches are cast on at certain intervals, and pipes fitted thereto in connection with the main sewer, or still smaller pipes in connection with each drain from the houses. These pipes should be smallest nearest the fan, and varying in diameter to the extreme end of the main suction pipe. We consider, that by this arrangement of graduated main and feeders, that the draught would be equalised throughout the entire length of pipe.

When it is desirable to lead a pipe from the main into each house drain, it must be placed between the sewer and the trap, fitted to the drain pipe. These feeders must be small in diameter, so that their combined area does not exceed the area of the suction pipe, as likewise to embrace as many house drains as practicable. For sake of illustration, we will take all the feeders of an uniform diameter of ½ an inch. The area of the 30 inches suction pipe is 706 square inches, and as the area of ½ an inch is ·196, it will require 3,600 feeders to make up the area of the 30-inch suction pipe, or, in other words, 3,600 house drains will be in communication with the suction fan. As the fan discharges 25,000 cubic feet per minute, each feeder would be drawing from the sewers, say, 6·94 cubic feet per minute, or 416 cubic feet per hour. Thus it will be seen that the sewer air would be gently drawn out over the entire area to be ventilated.

We will now assume that a street contains 320 houses to the mile, the houses, of course, being on each side of the street. As there are 3,600 house drains to be ventilated, the total length of the street would be 11¼ miles. This shows the capability of a suction fan discharging 25,000 cubic feet of air per minute. We consider this arrangement of small feeders extends the area to be ventilated. Were the feeders one inch in diameter more air would be drawn through each, but there would be only 900 house drains ventilated, and the mileage would be reduced in proportion. In another arrangement, larger feeders are fitted to the main suction pipe, and placed in communication with the main sewers. These pipes would be placed further apart than the former arrangement, and graduated from a small diameter at the end nearest the fan, and increasing in diameter towards the extreme end, thereby tending to equalise the draught throughout the entire range of piping.

In some situations the main sewers may be of sufficient capacity, so that the suction pipe could be hung from the roof. It should be pierced with holes at certain intervals, which would act as feeders, drawing off the gases immediately over the parts when generated, and we consider all new works should be so arranged when practicable.

In the meantime, we have to deal with existing arrangements. In some towns, steam-power would be preferable for driving the fan, and in other towns water pressure may be adopted. In laying down this proposed pneumatic mode of ventilation, central situations must be chosen. The area to be ventilated we will assume to be four square miles. A powerful suction fan must be erected centrally in that area, and placed in connection with a circular suction box, from which the various suction pipes would diverge. These pipes would be arranged through the main streets and cross streets, in a similar arrangement as for the distribution of gas for lighting purposes, and the feeders carried into the house drains, or in direct communication with the sewers, in the same way as the small gas pipes are taken into our houses. The one system of piping is identical with that of the other; the gas from the gas works is delivered under pressure; the pneumatic method of ventilation supplies air to our sewerage systems, by the exhaustion of a large volume of air drawn out of a system of piping, which, if properly arranged, cannot create negative pressure in the sewers, and which, we consider, would prove a great blessing to the community at large, by the thorough ventilation and purified dispersion of sewer gas carried up high chimneys, far overhead.

ON THE SUBSTITUTION OF THE PAIL SYSTEM FOR THE PRIVY MIDDEN SYSTEM IN NOTTINGHAM, AND ITS EFFECTS IN REDUCING THE MORTALITY AND SICKNESS FROM ENTERIC AND CONTINUED FEVERS.

By **Edward Seaton, M.D.,**

Medical Officer of Health.

The following paper relates to my experience in Nottingham, during the five years 1873—1877, of the effects produced by the substitution of the pail-closet for the privy-midden system, with regard especially to the prevalence of enteric fever and simple continued fevers, diseases which are grouped together by the Registrar-General under the one heading, "Fever."

I should explain, at the outset, that the circumstances under which Nottingham is placed, as regard its dwellings, is somewhat peculiar, and, as far as I know, without parallel in any other town of about the same size. Previous to 1851, the old town, as it then existed, was confined within very narrow limits, and was described as the most densely built on of any in the kingdom; for, though the borough included an area of nearly 2,000 acres, the greater part had been reserved as commonable lands, and was not available for building purposes. It was not till 1851 that the restrictions were removed, the land thrown into the building market, and the natural growth of the town allowed to take place. The new town, which has grown up around the old one during the past quarter of a century, differs as widely as possible from the older part, to which it is directly contiguous.

The streets of the latter are narrow and tortuous; leading from them are numerous courts and alleys which are mostly *cul de sacs*. The houses consist, in large proportion, of those built on the back to back principle, of which there are about 8,000. It will be easily understood, therefore, that the evils of the privy midden system would be present in their worst form in such a district. Upon the nature of these evils it were unnecessary to expatiate in this place.

It was, then, the peculiar nature of these circumstances that almost forced upon the Health Committee, ten years ago, the adoption of a system of removing excreta by tubs or pails, for the effectual abatement of the nuisances that were so rife. Some trials were at that time made by Mr. Richards, who has for many years been the chief sanitary inspector, and who has paid great attention to this subject, of the working of this plan in a few isolated cases. These subsequently became more numerous as the results proved satisfactory, and so, by very slow degrees, the system became adopted. By very slow degrees, at first, however, as at the end of 1872 there were only 363 closets. Since that time, and during the period to which my own experience relates, the progress has been much more rapid, and at the end of 1877 there were as many as 6,000, including those substituted for middens and those attached to new houses.

Besides fæces and urine, the pails receive the ashes and dry domestic refuse, and in this respect the system differs from that at Rochdale, Manchester, and Birmingham. There being a good agricultural district around the borough, there is no difficulty in disposing of the crude stuff, and as yet there has been no necessity to manufacture manure. The chief reason, therefore, for keeping the ashes, &c., separate, does not exist in our case, and the great advantages of mixing the deodorising and absorbing materials with the excreta are retained.

Let us take now the facts as regards sickness and mortality from fever. For this purpose, I have compared the figures for two periods of five years each—a time sufficiently long to allow for epidemic influence. The returns of deaths, with the exception of those for 1868-1869, which are taken direct from the returns of the district Registrar, are taken from the Registrar-General's periodical returns; those of sickness, from the returns of the General Dispensary, which are the only ones available for the purpose.

The following table sets forth the comparative statement:—

I.—QUINQUENNIAD. (1868-1872.)

Population 85,000. *Privy Midden System Prevailing.*

Year.		Sickness. Dispensary. Fever.		Deaths. Fever.
1868	....	113	....	49
1869	....	147	....	47
1870	....	221	....	106
1871	....	137	....	116
1872	....	130	....	77
Total....		748	....	395

II.—QUINQUENNIAD. (1873-1877).

Population 95,000. *Pail Closet System partially taken the place of the Privy Midden System.*

Year.		Sickness. Dispensary. Fever.		Deaths. Fever.
1873	....	104	....	70
1874	....	137	....	45
1875	....	111	....	70
1876	....	123	....	40
1877	:...	74	....	31
Total....		549	....	256

The difference is very striking in the total amount of the sickness and mortality for the two periods: it is still more so in proportion to the population. For the first period, the annual mortality was in the ratio of 9·2 per 10,000 of the population. During the second, it was only equal to 5·3, a diminution of more than one-third. The amount of sickness, as evidenced by the returns from the dispensary, was also diminished by nearly one-third.

But, it will be said, have there not been other sanitary improvements progressing coincidently, and are they not of a nature to reduce the mortality? How about your water supply and drainage, and have you not better hospital accommodation, for the isolation of cases of this kind? It would be difficult or impossible to eliminate each of these conditions, and to state definitely to to what extent they may have shared in the results that have been attained. With the exception of the first, there is no reason for attributing any share to the conditions above mentioned.

A great deal of attention has been given to the sewerage, but it has been entirely in connection with its disposal. As regards internal sewerage arrangements, there has been no improvement whatever. In fact, our position in this respect, of late, has not been so good as it formerly was. As regards hospital accommodation for typhoid fever, we are placed now exactly as we were ten years ago, so that both sewerage and hospital accommodation may be set aside.

As regards the water supply, I am not able to speak with equal certainty. The town has been supplied always by a private company. There were but very few private wells, and these, about thirty or forty in number, were closed when the Public Health Amendment Act of 1874 was passed. The public supply was chiefly derived from a source of unquestionable character, but a limited part came from others more or less open to objection. There have been some improvements in this respect. Of the three sources open to objection, one has been discontinued, another only used occasionally, and an additional supply, of the same character as that first mentioned, has been obtained. It is noteworthy, however, that the one questionable source—a well sunk in the bunter beds of the new red sandstone rock, in a populous district—which still remains in use, has been, on good grounds, suspected of being concerned in the spread of typhoid.

On the whole, though improvements in the public water supply may have been the means of diminishing, to some extent, the amount of fever in the district, it has not, I think, contributed very largely to that result.

So far, the facts I have brought forward show a remarkable coincidence between the extension of the pail closet system, and the reduction of sickness and mortality from enteric and continued fever. My knowledge of the other sanitary circumstances of the district leads me to place them in the relation of cause and effect. Moreover, this assumption would be entirely in accordance with the accepted facts with regard to the etiology of this disease, either upon the view of its pythogenic or simple filth origin, or upon the more widely received doctrine of its connection with specific filth-borne germs.

But other facts have come under my observation during the five years referred to, and since, which furnish proof of another kind, and show the dangers arising from privy middens, specially when common to several houses. I will mention two instances in which this was forcibly illustrated, and which formed the subject of a special report by me at the time to the health committee.

There is a yard in the crowded part of the town called Parrott's-yard. There were a block of four privies and a midden, for the use of 19 houses altogether; some of these were in the yard itself, and others back to back in the adjoining street. The people from these latter had to come by a circuitous route to the closets, and to pass other houses which had the use of another block. In 1875, enteric fever was prevalent in the district, and cases occurred in these houses among others. The pit was cleansed and a quantity of strong carbolic powder used. The next year, fever reappeared in the yard, and was limited exclusively to the occupants of the houses using the closets aforesaid. There were in all nine cases, and but little or no illness of the same kind in the immediate neighbourhood. Parrott's-yard stood out as an infected spot, in which the disease was endemic. Again measures were taken for the disinfection of the pit after it had been cleansed. In the summer of the following year a case occurred in the practice of the dispensary to which I am attached, of typical enteric fever, in a child of five years old, in one of these same houses. How far this outbreak might have extended I cannot tell, for immediately steps were taken to compel the alteration of the privies into pail closets, and since that time there have been no more cases. The disease, which appeared to be endemic in this locality, has been literally rooted out.

The second group of cases refers to a little street, known as Snow-hill. In this and the adjoining street, Richmond-street, there were, in 1875, 27 houses using a block of eight privies and a midden of the most abominable construction among the occupants of these houses there were several cases of enteric fever. I cannot say how many, as at the time it was very prevalent in the district, and I received no systematic information of cases.

In November and December of 1876, the next year, there occurred quite a local epidemic in these same houses; among the occupants there were no less than 19 persons attacked, and the remarkable fact was that the occupants of houses situate higher up the street, who had the use of a separate block of pail closets, were free from illness. There was only one case, that of a child who passed much of its time in one of the infected houses.

There were no other circumstances to account for the outbreak. The water was from the public supply, and there was no reason to call this in question, the rest of the neighbourhood supplied from the same source being free. There was nothing to direct suspicion to the milk, the only reasonable inference was that the infected privy pit had been the cause of the mischief.

The case was dealt with summarily. The privy pit was filled up and pails were substituted. In this instance too, we are justified in saying that the disease was eradicated, as since that time, with the exception of two sporadic cases, we have heard of no enteric fever in the district.

DISCUSSION.

THURSDAY, MAY 15TH, AND FRIDAY, MAY 16TH, 1879.

The proceedings of the Conference commenced on Thursday, May 15, the chair being taken by Lord ALFRED S. CHURCHILL, Chairman of the Council, who expressed his regret at the absence, through illness, of the Right Hon. James Stansfeld, M.P. (Mr. Stansfeld presided at the afternoon sitting).

The Chairman read the report of the committee appointed to adjudicate upon the essays sent, in response to the announcement that the Council of the Society offered one gold and three silver medals, for the best suggestions for dividing England and Wales into districts, for the supply of pure water to the towns and villages in each district. None of the essays were considered worthy of the gold medal, but a silver medal was awarded to Mr. Frederick Toplis for his paper bearing the motto "Better Late Than Never;" and one to Mr. Joseph Lucas for his paper with the motto "Gutta cavat lapidem, non vi, sed sæpe cadendo." He then called on Mr. Toplis, Mr. Lucas, Mr. Goslin, Mr. Atchison, Professor Ansted, and Mr. Birkett, successively, to state the main points of their respective essays.*

Mr. Lucas said he had long ceased to advocate horizontal wells. He was not an engineer, and had not pretended to do more than offer very general suggestions, founded not on his own observations, but on the theories of others. The moment he began to use a tape-line level, he assured himself beyond doubt that horizontal wells would not be at all desirable.

The Chairman then invited discussion on the various essays which had been contributed.

Mr. John Evans, F.R.S., felt that this subject was one of great importance to the country generally, and especially to those places where, at the present moment, the water supply was insufficient in quantity, or impure in quality. No doubt many of the suggestions made in these papers would add materially to the practical means of carrying out an efficient water supply throughout the kingdom. There could be no doubt that there should be some division into districts, and that there must be over the principal districts a certain number of Commissioners, or persons in authority, who would act in accordance with the Local Government Board. It appeared to him that the Board must be the central authority under which all these minor bodies must be placed, but what he wished more particularly to point out was this, that as the law at present stood, there were many difficulties in carrying out any scheme of this kind generally throughout the kingdom. In the first place, there was the enormous cost which would be entailed on any Government which undertook to lend a sufficient amount of money for carrying out the water supply for the whole country. That raised a second question, how far it would be desirable to supersede existing water authorities by purchasing their works. It did appear to him that there were three distinct classes of places requiring water supply: first of all, the large towns, in most of which an efficient supply existed, either the property of the corporations, or in the hands of private companies; secondly, there were the smaller towns, in a great number of which private companies had started, who were supplying the inhabitants at a moderate amount of cost; they had found the capital, and it appeared to him in most cases it would be needless for that capital to be taken over by parishes, and thus add to the amount of money necessary to be borrowed for purposes of this kind; thirdly, there were those small country villages, where the population was sparse, and where in many cases the water supply was not wanted so much generally, as in particular instances. In order to obtain a water supply in a country district lying at some distance from any gathering ground or good source of supply, the amount of capital necessary to lay out in works amounted to so large a sum, that any rate on a district supplied fell almost too heavily upon it. There were always a certain number of houses in which there was a sufficient supply, and the owners objected to being taxed for the benefit of their neighbours. The principle hitherto adopted by the Local Government Board was, that where the water supply was required for the central portion of a parish, the rates should extend over the whole parish, land being taxed at the rate of one-fourth the amount of house property. That had on the face of it a certain amount of fairness, but practically it was not fair in a great number of cases. Where there were in a parish various centres of population, some of which were already amply supplied with water, it was very hard that they should be taxed for the supply of one-third or one-fourth of the population which was in want of it. Again, the incidence of taxation was by no means fair. He knew a case in his own neighbourhood, where a scheme was proposed. Among the ratepayers was the occupier of a water-mill, who was rated at £400 a year, and the rate upon him would be the same as if he occupied a mansion at £400 a year, and required a large amount of water; but practically he did not want a drop, and he said so long as the principle of taxation is so thoroughly unfair, he should object to any scheme of the kind being carried out. He wished rather to point out the difficulties which existed, than to argue the general question, and this was a feature of considerable importance. It seemed to him that the area of taxation need not extend over a whole parish, but might be limited, either for water supply or sewage purposes. That area should, in the first instance, be taxed, and if the rates for sanitary purposes exceeded a certain amount, the residue should fall on the remainder of the parish. He could not but think that some such scheme as that would be beneficial in many respects, and would remove one of the difficulties that stood in the way of obtaining a water supply. But there was another ground on which opposition was raised, and that was the utter want of equity which seemed to prevail in the mind of those who organised water schemes. He need only refer to the great scheme brought forward by the Metropolitan Board, which to his mind showed a complete want of appreciation of the ordinary principles of moral equity. They applied not only to purchase the property of existing water companies, but were also going to lay out an enormous sum in procuring the supply in duplicate. From whence? From the chalk districts around London, the water of which was already appropriated; but they were not prepared to make any compensation to the owners of the rights in the water which they were about to remove; so that, practically, it came to this, that they claimed the right to sink a well in porous soil by the side of a river, to lay the river dry, and to pay no compensation whatever for the abstraction of the water. If schemes so utterly wanting in ordinary equity were brought forward, we could not be surprised at a great deal of opposition being raised. It appeared to him that existing rights, whether in rivers or springs, or any water which arose from perennial springs, must be considered, or else an amount of opposition would be raised which was quite unnecessary. If the schemes brought forward were founded on equitable principles, no one in these chalk districts could possibly object to the use of the water for the supply of the inhabitants of the neighbourhood, for it mattered not whether it was taken direct from the river or from a series of wells, but directly it was proposed that this water should be taken and carried away to a distance, and sold at a profit to somebody else without any compensation being given, everyone's feelings were aroused against the injustice, and opposition was created.

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* These Essays are printed at pp. 1-71. Mr. Birkett subsequently withdrew his Essay.

Professor Ramsay, F.R.S., being called upon, said he came quite unprepared to speak, although he had given a great deal of attention to the subject, particularly to drainage areas, the qualities of the waters of different rivers, and also to the question of these large underground supplies of water which could, in many places, be obtained without touching the river waters at all. Mr. Evans had broached a number of matters of detail which no one could come to any conclusion about now, except as to the abstract principles of justice he had mentioned, and which would necessarily have to be borne in mind if any great scheme were carried out for the supply of water. Then all the different drainage areas of England must of necessity be taken into account and treated with in some equitable manner. He knew the various drainage areas of England well, and some 20 years ago had constructed a map showing those areas in relation to the geological formations of each. He had no doubt that if ever a large comprehensive scheme were formulated, and after having been well thought out, were brought into action or recommended, England must in the main be divided into given areas of drainage more or less connected with the various towns and villages lying within those areas. Any geological map would show that in the South of England, east of Devonshire, and over almost all the half of England, up to Durham and Northumberland, the formations were calcareous to a great extent, and the result of that was that nearly all the rivers that ran into the German Ocean and English Channel east of Devonshire were more or less hard in quality; but it did not necessarily follow that the water was essentially bad. If it were possible to get soft water into those areas, it would be desirable, but if it were impossible to do so at a moderate expense, then the people who lived in them must do the best they could with the water they had. One gentleman had alluded to the soft waters of the Cumbrian district, and he was perfectly correct. The rocks there are partly slates and grits, but a very large part consist of feldspathic traps and volcanic ashes, the water which came out of which in springs was always of a soft, pure quality. He also said that the waters of Wales were, as a rule, hard, but he begged leave to differ from him in that respect. He did not think there was anyone in the British Isles better acquainted with Wales than himself, for there was not a mountain he had not been on, and either personally surveyed or superintended its survey. It nearly all consisted of silurian slates and igneous rocks, and all the rivers which flowed eastward were soft in quality. Here and there there were impurities resulting from mines, but not to any very great extent. In one place in Cardiganshire, the waters had been rendered impure by the crushing of lead ore, and the refuse ran into the rivers to such an extent that the fish were poisoned, but these were rivers which all flowed to the west into Cardigan Bay, and would not be wanted for the supply of water anywhere to the east of the great water-shed of North Wales, which ran north and south no great distance from Cardigan Bay. The water that ran out of the old red sandstone was somewhat harder, but that all drained into the Severn or its estuary, and the same was the case with the water from the coal measures. If any large supply of water were wanted from Wales to supply London, or any other towns to the east, an ample supply could be obtained from those deposits, soft and agreeable in quality. There was another grave point with regard to wells that might be sunk into underground supplies of water, though it would be useless to go into that matter thoroughly unless he had two or three hours to do it in, and geological maps. He would simply say this, that there were great areas in England where vast quantities of water could be obtained if tapped judiciously. He saw before him Mr. Bright, late Mayor of Leamington, who had had a deal of experience on that point, a well having been sunk there by Mr. Ramsay's advice in the keuper sandstone, and now the township was supplied with four times as much water as was required. He was also connected with the supplying of Brighton with water. They stopped sinking three times, but he insisted on their going on until they pierced the lower greensand. They went on, and it was very fortunate the men were all at dinner, when a thin stratum of gault having been left above the greensand, the water suddenly burst up and filled the well, and would have drowned them all had they been there. These supplies could not be obtained everywhere, but in many places they could, and were of very great importance.

Mr. G. J. Symons, F.R.S., said there could be no doubt of the desirability of adopting some general scheme instead of the present scramble, in which it was simply a question which was the richest town and the most reckless, because the most bold and ambitious went to Parliament with a great scheme, having made up their minds to get water from somewhere or other. If they found there was any opposition in the district, they simply bought it off, and then they were like Manchester in possession of Thirlmere, whether or not it was a wise thing for the water to be appropriated to that particular town. Parliament had no adviser on the subject, but simply took the evidence brought before it in the Committee-room, and if that were all on one side, the Bill was forthwith passed. So it happened this year. The local opposition to the Thirlmere scheme had been bought off, and the question whether it was wise for one of the great national supplies to be appropriated almost exclusively to one town, instead of some broad, general, comprehensive scheme being adopted for the benefit of the whole of the North of England, that being a pure piece of public policy, did not come before Parliament at all. The consequence was, the Committee found the evidence all on one side, and Thirlmere, for all time to come, became the absolute property of Manchester. He could not think that that system was right; surely it would be an enormous benefit if there were some Court of Reference, or some authority who should be independent of the personal interest either of Manchester, Liverpool, or any other town, and should say whether it would be wise and right that the great stores which exist in two or three comparatively small localities should be wholly devoted for all time to one town, because as soon as the water supply was given to one town it was their property for ever; and if any intervening town wanted a supply in future from the Thirlmere district, Manchester would expect to be paid very handsomely for its present investment. The meeting was probably aware that the great bulk of the rain fell in Cumberland, Westmoreland, and North Wales. He quite agreed with Professor Ramsay that, practically, there was no difference between the water of the two districts; but that being the case, one ought to look at the fact that there were a large number of towns in which the populations and growth were rapidly increasing, and, consequently, the consumption of water. The bulk of the water practically came from one district, although at Dartmoor and one or two other places there might be a certain amount; but the bulk of the supply was all in one corner of the country. Now of these Cumberland lakes there were only three of any size, which were high enough to supply the greater proportion of the country without the extra cost of pumping, and if you had to lift the water, the expense would be very much increased even at the present time, and much more so in the future when coal became scarcer. There were then only three lakes sufficiently elevated to supply water by gravitation, namely, Thirlmere, Ulleswater, and Haweswater. Thirlmere was already bespoken by Manchester, and it was pretty well understood that Liverpool intended to get Haweswater. If they did, there would be less water left for all the large manufacturing towns, of Yorkshire and all the remaining towns of Lancashire. If these two most important lakes were taken away, there was a very small residue left behind. He could not think this was a state of affairs which would be contemplated with satisfaction in 50 or 100 years time. It was merely a question of expediency that some arrangement should be made by which the public aspect of this question should be put before Parliament separately from the private one of the particular towns which wanted the supply, or the landowner who asked for compensation for the water taken. There was one grand difficulty in connection with this subject, and this was the very large amount of pecuniary interests already involved. Mr. Evans was perfectly right when he said that it would be a most frightful undertaking for any Government to buy up all existing companies. No one knew how many millions of money that would take, and there was a great difficulty in the way of the introduction of any scheme. As the author of one of the papers remarked, it would be very easy to arrange for a water supply if they could only begin *de novo*; but the question was to get something which would work into existing arrangements without disturbing them more than necessary, but which would prevent in future any town snatching mean advantage over the rest. Another thing which perhaps had done some mischief was the map in the report of the Rivers Pollution Commission showing the polluted rivers of England. It had frightened a good many people, and he must confess his own opinion was, that it was one of the most exaggerated maps he had ever seen. If a partridge flew over a moor, you might say that a river flowing through that country was polluted to some extent, and he was inclined to think that some of the pollutions indicated on the map would not be more serious than arose from the sheep-droppings on the hills. Another remark in the 6th Report of the Commission was to the effect that rain-water was bad, that it had washed the air of all its impurities, and had done all sorts of things. He should not like to drink London rain-water; but still rain-water generally was soft and pure, and he was sorry to see this slur cast upon it. There was also a proposal made that this class of questions should be put under the Local Government Board. He did not pretend to know much about it, but he believed that the Local Government Board already had a tremendous amount of business under their charge, and he was inclined to think that this was too large a question to be put in a secondary position of that sort. At the last meeting of the Social Science Congress, Dr. Richardson suggested the appointment of a Minister of Health, and he could not help thinking that what they wanted was, the creation of new appointments in the Cabinet from time to time, in accordance with the growing wants of civilisation, because they had simply the same officers now as they had 100 years ago. The French had a Minister of Public Instruction, but they had none. This question of water supply was, to a great extent, connected with public health, although it was also a question of commerce, and he thought it would be very well if it could be placed under the care of a Minister of Public Health. What he principally desired to insist upon was, that something or other should be done to provide a central focus in which all the statistics bearing on this question could be collected together. They had had Commissioners without end, who made reports in endless variety, but no one knew where to look for the information collected, except it was to the valuable collection published by the Society of Arts, for which he felt greatly indebted to it. If this information were all collected, persons would be much better able to deal with this question of water supply than they were at present. He was glad to find that this meeting was entitled an annual Conference, and he hoped that the Society would keep at it till something definite was done.

Mr. Bright (Leamington) said he would narrate the facts which had occurred in that town to prove that there was a very large underground water supply, which might also exist in many other districts, and which might be a large factor in this question. He was rather alarmed when he heard one of the previous speakers propose that the whole of this country should be divided into districts, which should be supplied at the general cost of the whole of the inhabitants, because many had gone to a large expenditure for the purpose of getting a water supply, and it would appear manifestly unjust if they were to be taxed equally with those who had done nothing at all. In Leamington they prided themselves on being rather in advance of the public generally on most questions, but especially on the water question. Like many other towns, they were suffering from the pollution of the small river from which they used to obtain their supply. When he went to Leamington forty years ago, the brook was very pure, but modern civilisation had gradually progressed up the whole of the water-shed, and the riparian proprietors higher up were adopting modern conveniences, and used the brook from which they got their water supply to get rid of their sewage. The result was that things got gradually worse and worse, until the absolute existence of the town as a sanitary resort was in great danger. They were indebted to

Professor Ramsay for an entire change. With the greatest possible kindness, that gentleman gave him he information he had collected in the Museum in Jermyn-street, and which he was always ready to give o any one in want of it, and, acting on that, in spite f the most persistent opposition from ignorant people, hey bored for a short distance into the earth in the new red sandstone, and found a perfect river of underground water. Owing to the people having to be ducated gradually, they had been some six or seven years about it; but during the whole of that time, upported by the advice and assistance of Professor Ramsay, they had gone on until, three months ago, hey opened the waterworks to the public with the ollowing results:—They found the water at about 00 feet; they bored another 100 feet by an artesian ore, but from that they did not get much. The largest supply was got within 110 feet from the surface. For the town of Leamington they required half million gallons per day, allowing 25 gallons per head; but they found they could pump two and a-half million gallons without ever getting the well within 16 feet f the bottom; in fact, in endeavouring to get to the bottom for the purpose of ascertaining that everything was properly done by the divers, they had been pumping more than three million gallons, but they had not ucceeded in reaching the bottom, the fact being that he more they pumped the more water they got. The reason of this was that the fissures in the rock got cleaned out, and the water came in with greater apidity. No doubt there were many other districts qually well situated if they only knew it, and he hould recommend any one who thought they had water beneath them to obtain the advice of Professor Ramsay upon it.

Capt. Douglas Galton, C.B., F.R.S., said he had read all he papers sent in very carefully, and the suggestions made were certainly of very high value. He regretted they had not been more fully alluded to; indeed, many of the peakers did not seem to have made any allusion to them. One gentleman recommended that the rivers themselves hould be taken as the boundaries of districts, with which he certainly did not agree, but there were other points of merit in the paper worthy of attention. The whole question, however, seemed to him now to have come to a ocus, and everyone concurred in admitting that England hould be divided into districts of some sort for the purpose of regulating the water supply. There might be differences of opinion as to how those districts should be constituted. There was also a general consensus of opinion on another point, namely, that the information which existed should, as far as possible, be brought to a ocus. It was quite clear that a very large portion of he information rested in the hands of the Geological Survey Department, and probably there was no one who had a greater knowledge of the geological questions affecting the water supply in this country than the present Director-General of the Survey, Professor Ramsay. There were other departments which were strictly concerned with this matter, but now they were all scattered about. The Local Government Board seemed to be the legitimate focus for this information, and whether the Minister of Health were to be appointed or not, at all events that Board must be the framework on which the Ministry of Health would be hung. It seemed to him that the most sensible thing to do, as a preliminary step, would be to place the Director-General of the Geological Survey, the Director of the Ordnance Survey, the Registrar-General's Department, and a department for recording the rainfall, in official relation with the Local Government Board, so that, at all events, all the Government departments which had information bearing upon this question, and upon questions relating to the health of the community, might all be brought into immediate communication under one minister, who could thus easily organise a machinery for collecting and diffusing information upon questions relating to water supply. The Ordnance Survey was originally devised as a military department, for the making of a military map of the country, but as soon as that was completed, the War-office, not liking to bear the cost of it, tried to get rid of it; and, the only department they could think of transferring it to was the Office of Works, which is now, of all others, the one least suited for the purpose, seeing it has nothing to do with anything outside London, except perhaps the building of a few post-offices, and there is no one in that department who has any special knowledge of a matter like the Ordnance Survey. It would have been, therefore, far better to have transferred it to the Local Government Board. Although the Local Government Board was so much found fault with, he believed it was the department which must eventually have charge of all these matters. Parliament was at present concerned with a Bill for the river conservancy, and as Mr. Atchison had remarked, river conservancy and water supply must go hand in hand. Whether the water was got directly by pumping from underground, or percolated by the overflow of those underground waters into the rivers, it all came from the rainfall, and, except in cases where large aggregations of population exist, as, for instance, London and Manchester, and where, therefore, the requirement might exceed the available local supply, districts should be so arranged as to be self-contained in regard to the control of their water supply and drainage; each district must consider for itself what are its own wants, and arrange for their supply.

The Chairman suggested that the Conference should now go into the general question of supply of water in connection with the health of districts, and he would ask gentlemen who had written papers on the subject to state the substance of them.

Mr. A. H. Brown, M.P., having stated the substance of his paper on "The Incidence of Rating for Sanitary Purposes in Rural Districts." (See p. 72.)

Mr. J. Evans said that he had not seen Mr. Brown's paper previously to making the remarks he had offered that morning, or he should not have gone over much the same ground, for which he must apologise. At the same time he must express his satisfaction that a gentleman who had given so much attention to this important question had so far agreed with him.

Mr. Edwin Chadwick, C.B., expressed his concurrence with the idea expressed by Captain Galton, that the various administrative departments in any way connected with this subject ought to be brought under one head. The further you went the more you found the necessity of centralising authority and centralising knowledge in this direction, and such knowledge as was brought forward on that occasion would be of immense value to the country. The great obstacle to reform in this matter had been touched upon by Mr. Evans, viz., the question of the purchase of various interests, and one important function of any general Board, besides centralising knowledge and authority, would be to adjudicate between rival interests as to questions of compensation. That was now going on to some extent under the Local Government Board. The tendency in very large places was to place water supplies under public authority, to put them on a footing in which payment should not be made for a trading profit, but for a service rendered. Before that could be brought about no doubt companies and private enterprise were very serviceable, and he himself had promoted private companies for water supply. The Local Government Board had been adjudicating on questions of compensation between owners and towns, and it had been, on the whole, he believed, done in a manner satisfactory to both parties, and was generally carried on voluntarily. It was a great misfortune that the principle had not yet been brought to bear, as it ought to be, in the case of the metropolis. The obstacle there was the question of purchase, which was to be settled by some sort of arbitration or judicial intervention, and that ought to have been done a long time ago. The truth was, the Metropolitan Board of Works seeing nothing done by the Government, thought it only right on its part to make an effort to do it, and although it had not been successful in getting a good plan, he thought himself it was very unfair to surcharge the individual members of that Board heavily for an effort which was very good in itself, although it might have failed. One ground for putting this water supply on a public footing was, that it might be carried out far better and cheaper than it could possibly be by a company. Companies could not have control over interior works, and the means of carrying the water away; but both ought to be under one authority, and that should be a public one. It was lamentable that whilst that was the general tendency, and the results generally were satisfactory, the metropolis should remain an exception. It had been referred to Dr. Farr and himself to examine as to the terms of purchase, and they found the amount of waste from separate works would be equivalent to a rate of 6d. in the £, and that if the companies were bought up now at the rate they claimed for themselves of 10 per cent., it would not amount to more than a rate of one-third; whereas by the stream of decisions of the Local Government Boards throughout the country, it would not amount, if adjudicated upon on the same principle, to more than one-sixth of the waste now going on. A central Board could only act on the Local Government authority, but there was a great want of scientific knowledge in the localities, and he himself had contended for putting not only the roads, but the water supply of a county, under a county engineer, as had been done in Ireland with great advantage.

Mr. W. H. Wheeler then stated the substance of his paper, on "The Water Supply of Rural Districts." (See p. 78.)

Mr. C. N. Cresswell asked permission to make a few remarks on the paper of Mr. Brown, which seemed to him to be of peculiar significance at the present moment, and he should not like it to pass without discussion. It would be a matter for great regret if a paper, which was the result of so much thought, experience, and well directed energy, were to be dismissed as if it were the crude expression of an uninformed opinion. He was so far disposed to agree with Mr. Brown, that he could hardly raise a discussion upon his paper; nevertheless, he would start a difficulty, for the sole purpose of enabling others to hang, as it were, one peg on another, and thus debate the question which, in his humble opinion, Mr. Brown had not exaggerated when he said it lay at the very root of that sanitary progress which they came there to discuss and promote. When Mr. Brown told them it was useless to come there and speculate on theories or discuss methods unless they removed the obstacle which lay at the foundation of all progressive legislation, he struck a chord which ought to vibrate through the mind of every intelligent sanitary reformer. That great obstacle was simply this,—you could only effect sanitary improvements by means and money, by a taxation of the people, and unless you had a system of taxation based on equity and justice, all political and social action in this country became impossible, by reason of the prejudice which you created, and unless you could remove that moral obstacle you might as well try to remove mountains by mere faith. Mr. Brown told them that his experience showed that the inequitable incidence of taxation, particularly in rural districts, had for years past prevented that progress which all enthusiasts twenty years ago hoped to have seen. "Why," said one gentleman, "should I pay for the benefit of people living far away from me without benefiting myself in the slightest degree? I have already provided my house and those dependent on me with everything necessary for their health and happiness. I have erected my own private gas works and water works, and in the middle of my park I have constructed an enormous cesspool which drains the houses and stables of those who live in my immediate vicinity. Why then should you make me pay for the benefit of a town which lies a mile and a-half away? It shows either that there is injustice at the bottom of the transaction, or that there is some original defect which needs redress in the arrangement of the sanitary area to which I belong." Now, the President of the Conference, whose absence they all deplored so much, had again and again called attention to the absolute necessity of a rearrangement of sanitary areas; and he would suggest to Mr. Brown, who was well able in the Legislature to make his voice heard, that that question also lay at the root of the matter, and that, if the sanitary areas were altered and rearranged with some degree of logical sequence, one of the difficulties to which he had alluded would vanish. In many cases, there were in one sanitary area two or three villages or hamlets, combined under one rural sanitary authority without the slightest rhyme or reason, but by mere local or geographical accident. By altering that you would, to a great extent, remedy the evil, because you would make it impossible that one portion of the district should be made to pay for the exclusive benefit of another. Again, it was said that it was unjust that the agricultural interest should be taxed for a benefit which they never could receive. He would submit to Mr. Brown that, in the Public Health Act, and in the incidence of rating established by Parliament, the interests of agriculture had been already considered, the land only paying one-fourth, because it was thought that the great cause of expense in these sanitary districts was the removal of sewage from dwellings; that it was the houses which, to a great extent, caused the mischief, and that on them should lie the expense of removing it: and, therefore, that on the land the taxation should be only one-fourth. Now, with regard to water rating, there could not be the slightest doubt that the principle advocated by Mr. Brown was logically correct, namely, that those who drank should pay; but when you came to drainage, you were met with this difficulty at the threshold—How far could you say that any person in a district or parish was left unbenefited by the improvement of drainage in the district? It would necessitate a department of health, and a total alteration in the system of rating, besides special commissions probably to do sanitorily, what had frequently to be done politically in ascertaining the boundaries of political boroughs. It would be found necessary, if this proposed readjustment were brought to maturity, to describe topographically, by parochial maps, every house, and the amount of contribution which each should pay, whether 100, or only 25 per cent. Then it must be recollected that although possibly in a particular parish or district the houses in the actual village profited more directly by any work of sanitation than those at a greater distance, nevertheless, the object of sewage removal was in almost all cases to prevent the pollution of rivers, and that those who might not be in any way contributing to the pollution were still benefited by the expenditure, which made the river that flowed through their own district pure above and below. Therefore, to lay down a proposition that they were not all within a certain area equally interested in the work done, opened the door to a great difficulty as to how far it was possible accurately to state, and, to decide the exact proportion between those who had to pay the whole, and those who claimed to pay less. He submitted these difficulties simply for the sake of raising an argument, because he thought Mr. Brown had conferred an obligation on the meeting, and at any rate, that the paper should be discussed.

Dr. Tripe said the question of rating was one of extreme difficulty; the money question was at the bottom of it, because you could not expect persons, as benefactors to the public, to advance money unless they could see a reasonable return for it. It would be simply impossible to expect a small village, where there were few houses, but with large building capabilities, to defray the cost of waterworks. It you laid the whole of the costs on those who first occupied the houses, what would you do with those who occupied the houses afterwards built on the same area, and partaking of the same advantage. Was it proposed that they who came afterwards should pay a smaller sum than those who were there first and assisted in the development of the water system? The ame thing applied to drainage. Therefore, in order to provide the means for supplying water, it seemed to him hat the rates must, at any rate, be chargeable, and if hey were chargeable, then came the question how that was eventually to be defrayed. This seemed to be one f the great difficulties in carrying out Mr. Brown's proposal. The plan seemed equitable, and was equitable f it could be carried out, but he did not see how it could be done. He wished to speak, however, rather on the question of wells *versus* rain-water, which was one of very great importance. All medical officers of health and analysts who had had any experience knew that well-water was the most uncertain supply of all, unless he well was constructed with iron pipes or some impermeable tube, carried down below the first impermeable urface, the water must of necessity become contaminated with surface drainage. The capability of the soil taking out all noxious matters from the water was limited, if it were water-logged then the change could not go on, or only to a limited extent. The oxygen contained in the interstices of a porous soil not water-logged, acted on organic matter, and converted it into nitrates and nitrites, which were practically innocuous, and in that way you might get, for a length of time, well-water comparatively pure, but after a time, in consequence of continued rain, it got surcharged, the rain would carry with it a large quantity of surface matter, and the well suddenly became impure, and if yphoid excreta had been thrown on the soil, that found its way into the well, when disease occurred and spread. t was not confined to those who immediately partook f the water but spread everywhere, and in that way diphtheria, typhoid, scarlatina, and other diseases were diffused. The water in which scarlatina patients had washed might be a fruitful source of disease in this way. Milk also got contaminated from mixture with water, and this so-called milk was, he believed, a cause of yphoid epidemics; he did not believe they arose from he milk of a cow who was affected with the disease. Now, it was a very serious thing indeed for it to go forth to the public that well-water was a good and sufficient upply, unless the wells were made in such a way as to ut off all surface water. With regard to rain-water, you knew the limit to which it could be charged with foreign matters, because the analyses made by Dr. Angus Smith of rain-water in Liverpool, Manchester, and London, showed the extreme limits to which such water could be injured; and how any one could suppose he matters brought down with rain, which could be filtered off very easily, could be likely to be more injurious or objectionable than surface water finding its way into wells, was astonishing. He felt strongly on his matter, and did not like such a thing to go forth unchallenged.

Mr. A. H. Brown, M.P., said he knew there were many difficulties in connection with his scheme, but he should like to answer Mr. Cresswell on two points. The first objection, with regard to sanitary areas, would be found dealt with in his paper. Again, the last speaker had asked how it was possible to carry out the scheme he suggested. He had stated shortly how he thought it could be done, and the principle was already contained in an Act of Parliament, one clause of which was quoted in the paper. He believed it only wanted a little careful working to settle what would be the area of benefit for drainage. With regard to water, it was quite simple, because you only had to make the consumers pay for the water.

Mr. Chadwick said there were tables prepared by the Local Government Board for the distribution of charges over any number of years up to 60, showing how the distribution of charge could be settled equitably.

Dr. Wilson wished to confirm what had been said by Mr. Wheeler. A few years ago he was medical officer of a district near where Mr. Wheeler resided. He had analysed the water from a large number of surface wells, and he could only say he was never satisfied with the condition of any one of them. Then there came a question where the poor people of the Fen country could get their water supply from, because there were only these wells, next the navigable rivers, into which all the sewage of the district went, and, thirdly, the rainfall. In some of those districts, during the dry summer months, you found people paying 2d. for two gallons of water, which was a very serious thing for a poor man with a family; and, therefore, for the sake of both health and economy, it became a question how this difficulty was to be met. After seeing Mr. Wheeler's paper on the available area of every house to provide sufficient water by the rainfall, the difficulty seemed almost to have vanished. He had analysed the rainfall under different conditions, and, after passing it through what might be called a very rough filter, he found it was much purer than any other; and, in fact, it was a good, wholesome water, which he could recommend. He further tested its use it in his own house, the supply for which previously was so bad, that Professor Wanklyn's report of it was that it was a not very dilute sewage. His medical experience of that district would no doubt be borne out by others, that not only were there many organic impurities, but a large amount of mineral matter in subsoil wells which caused a great deal of disease. After a time, he was fortunate enough to convince some landlords and farmers, and induce them to make this change for themselves, and he was happy to say that the practice was spreading. It was a very necessary matter to discuss the larger question of how England was to be supplied with good water, but when you came to look at these districts in the eastern counties, which were very far from that line of water supposed to be brought from the lakes, it was another question, because the least possible expenditure necessary for bringing them within the range of that water supply would be so great, that it would for ever shut them out from any such benefit. They must, therefore, look to the rainfall collected from the houses, and also, as he had suggested, that from the churches, chapels, and schools, might be made available to store water during the winter, which would to a large extent supply, during the summer, any deficiency from the imperfect arrangement of houses. At a very small expense, each cottager might provide a rough filter, which would render the rain-water far superior to that usually obtained in the Fen land districts.

The Conference then adjourned for luncheon.

On re-assembling, **Mr. Stansfeld, M.P.**, took the chair.

Dr. Yeld said it struck him, when Mr. Brown was reading his paper, that the Act of Parliament he had recently introduced into the House of Commons was based on that paper, or that the paper was based on the Act. It was called the Public Health Improvement Act, and was a small Bill. They all knew that Mr. Brown was very happy in passing small Bills through Parliament, but in considering the rating question, the latter portion of the Bill was well worth the consideration of all urban sanitary authorities. He quite agreed that in rural districts some injustice might be done in rating properties which were a long distance from the village, and making them bear the burden of the water supply and drainage of the village, but in reference to urban sanitary districts it did not appear so unjust. In that Bill Mr.

Brown had a provision that for such purposes, in urban districts, a separate sewage rate should be made, but one consequence of that would be to give immense difficulty and trouble. Then there was another thing which was pointed out by Mr. Cresswell. It was a grave question whether in large districts, urban sanitary districts particularly, although a gentleman's mansion might be some little distance from the outskirts of the borough, and although he might not make much use of the drainage area of the districts, still in the matter of health he must be much benefited by the works carried out by the local sanitary authority. He therefore hoped that gentlemen representing urban districts would examine the Bill, and bring it before their local authorities.

Mr. Shute wished to say a word or two on the subject of reservoirs. Mr. Wheeler had spoken of the importance of collecting rain-water for houses, and the same principle might be carried further, as it had been done to a certain extent in the north by making reservoirs, probably because they had better sites for so doing than in the south. These reservoirs had a treble advantage, that they not only supplied pure rain-water to towns and villages, but prevented floods by storage, and were also useful as sources of power, being largely used for that purpose in the North of England. They could be usefully supplied in many rivers by making a dam below the weirs, without damming back the water in any way. Of course, to get a supply of pure water in that way, you must have a deep dam, because a shallow pool would soon get foul. In some places there might be difficulties in getting land, but with collective action they would not be insurmountable. He thought it would be of great importance to London to make reservoirs in the Thames valley.

Mr. W. H. Cutler, C.E., wished to say a few words on the question of rating—more especially with regard to water rating—before it was passed over, as this was a subject of very general interest, and one which it appeared was very little understood. Only a few days ago a large and influential deputation waited on the Home Secretary to bring before him the question of the charges of the London water companies, and objected that the water rates were increased from time to time, but they did not seem to have understood how these rates were levied. When those rates were first arranged, it was doubtless taken into consideration that a fair basis should be the value of house property, and in the Waterworks Clauses Act, and in various private Acts passed from time to time, the water rate was almost invariably based on the value of the premises supplied. He knew the case of a house standing on Castle-hill, Windsor, which, in the reign of Edward III., was worth 13s. a year, but was now worth £150. It would be absurd to say that the house was now to be supplied with water at a rate of 5 per cent. on the annual value of 13s., by which the water company would be very inadequately repaid for the supply. The water rate was based on the value of the premises supplied, because it was about as fair a way to get at the value of it as could be devised. The deputation before Mr. Cross the other day complained that the water rate was increased 50 or 100 per cent. for the same quantity of water, but then that quantity of water had gone up in value. It should also be taken into consideration that the water rate was not raised exactly at the time when money had depreciated in value, and although based on the gross value of the premises, that was almost invariably got at by the rateable value. The way the rates were levied very much depended on how the works were first constructed. If the works which conferred a benefit on a certain district were constructed by a sanitary authority, the necessary capital was borrowed, and had to be paid back in thirty years. It had been contended that it was only those who were actually deriving the benefit who should pay the rate, but that would not be at all a fair way of looking at it. Suppose the case of a sanitary authority supplying a town with water: in a certain street there might be 12 houses on each side; the owner of one side might wish to have his houses supplied with the water, but the man on the other side would not, saying he had already provided his houses with wells. The man who had the water would pay the water rate at the beginning when the capital was being paid back; but at the end of the thirty years the man on the other side might say that he found his wells had failed; he did not get so good a supply as he hoped for, and would have his houses supplied from the water-works; but the other man had already paid for the water works and this one would only now have to pay for the working expenses and interest on the money, which would be exceedingly unfair.

The Chairman asked what alternative Mr. Cutler would suggest?

Mr. Cutler said a compulsory rate. The money was generally borrowed on a compulsory rate, and he did not think that bore a sufficiently large proportion to the non-compulsory rate. The way to arrive at it would be to consider what part of the rate was devoted to paying back the capital. There was a great outcry now about constant supply, but that subject seemed to be generally begun at the wrong end, because the question was, were the water companies to have powers granted to them of compelling people to put their fittings in a state to receive a constant supply. No doubt it would be a great saving to the London companies if they could grant a constant supply, and if the fittings were properly constructed; but if there were a constant supply over the whole district, there would be immense pressure in the lower parts, and the waste would be enormous. He had taken a good deal of interest in this question, and had under his control some works which had been in operation since 1696. When he took them in hand he had to entirely reconstruct them, and he would undertake to say that they were now as perfect as any in the country. The water was supplied at a low rate very easily, and the supply was enormous; there was an immense amount of waste, but the water was easily and cheaply supplied, and he should be happy to show the works to any gentleman who would like to see them, on any Thursday. The works were situate at Eton, and supplied Windsor, Eton, and Clewer. There was a very low fall, hardly ever exceeding three feet, but that was sufficient to raise the water to the height required, the lower part being supplied by a French undershot water-wheel.

Mr. Chadwick asked if Mr. Cutler was speaking of a supply by a company or by a town?

Mr. Cutler said he was the proprietor of the works which had been in his family for more than a century.

The Chairman said Mr. Cutler had been dealing with two totally distinct questions, though they were sometimes supposed to be associated, because of the uncertain use of the word "rate." The rate which you paid to a local authority in common with all other ratepayers for a public object, whether you got a sufficient return for the individual payment or not, was a totally different thing from the rate or price you paid to a private company for an article which was supplied. He did not suppose the Conference would care to take up much time with the question of the London water companies, which was a very large subject, and was likely to have the attention of the Legislature ere long. He did not think, whatever Mr. Cutler's views might be (and there was something to be said, no doubt, from his side of the question) as to the justice of increasing the charge for water as the value of money decreased, and the cost of obtaining it increased, that the general argument would satisfy London householders, particularly those who paid large rents, and who were charged upon their rent, or on the annual value of their holding, which was put up at every valution of the metropolis, and which implied a heavier charge, without consuming more water, and without, as far as he knew, any increased cost in the production of the water for their consumption. It did not seem to have been a sound bargain on the part of the public, but it was a difficult question to deal with, and no doubt would have to be dealt with by the Legislature. With reference to the question of paying for certain sanitary purposes in rural districts, he agreed with Mr. Brown. He had shown, both here and in Parliament, that the absence of some greater elasticity in the statutory arrangements for the imposition of a charge for these sanitary improvements was a check on these improvements, and his paper opened with a category of instances in which real improvements, necessary in rural districts, were prevented by these difficulties. He believed every one in that room was aware that these difficulties did occur. If you had to deal with an urban population, you could deal with it *en masse:* but in dealing with an irregular, scattered, rural population, you wanted more elastic machinery. No one could doubt that the fair thing was that the consumer should pay for the articles produced for his use, but he could not pay in this case like a man who went into the market and bought a thing which was always for sale. A certain amount of capital had to be invested in the creation of water-works, which had to be paid off in a certain number of years, and to pay current expenses. The argument of Mr. Cutler was this, if he followed him aright, that the cost of construction ought not to fall entirely on those who, at the outset required the use of these water-works for their own purposes, and that was true, but without any alteration in the law, that state of things already existed. It would take 30 years to pay off the interest and principal expended in the construction of works, and during the whole of that period, every occupier who came in to use the water, contributed not only to the actual cost, but to the repayment of the principal and interest. If it were said that that might be so, but at the end of 30 years, the whole cost was paid off, and then those persons who originally had wells of their own, might come in and enjoy the use of those water-works without paying anything towards their construction, the practical answer was this, in all human probability long before that further extension would have become necessary. After all, these things were progressive. If the population increased, you had to add to the capital outlay, and in that way, those who did not contribute at first, did so at some later time. He had no objection to the statement of the principle, but he did not think it was an objection to Mr. Brown's scheme; it was a point to be borne in mind in the construction of clauses, so as to secure that no injustice, even in that unlikely case, should be committed.

Dr. Yeld asked if the same principle would apply to the drainage areas referred to by Mr. Brown?

The Chairman said, in his opinion, sanitary statutes required some further elasticity. He was responsible for the original conception of special drainage districts when he passed the Local Government Act, but that method had its disadvantages, because as soon as you constructed a special drainage area it became a rating area for all purposes, and the multiplication of small rating areas was an objection. Then the Act was not sufficiently elastic. In his opinion it was sufficiently so at the time in its principle, that you must not throw the cost of work, which was to benefit the small area, on the whole sanitary area. He wanted to introduce the principle, and he did so in the clause enacting the establishment of these special drainage districts; and he did not carry it farther at the time, for a reason which he had explained before, and which had to do with the methods by which you were compelled to work in framing Acts of Parliament. You had to frame them so as to pass, and you could not exhaust the whole of the subject logically. Practically speaking, you wanted to gain certain ground; you thought the time had come for exhausting a certain branch of the question, and you did so: or that the time had come for making another step further in principle, and you did that. You knew you had sown seed which would spring up and bring forth fruit some time, in the shape of an Amendment Act. That was not necessarily an evidence of incapacity or want of foresight in those who framed Acts of Parliament; sometimes it was an evidence that they knew their business. He was the author of the clause, and as its parent he was perfectly willing to admit its imperfections, and to say that Mr. Brown had drawn public attention to an imperfection which he, for one, was quite willing to see remedied.

The Chairman then invited discussion on the three geological papers of Mr. De Rance, Mr. Lucas, and Professor Prestwich.

Mr. Lucas stated the substance of his paper, "Water-shed Lines: Subterranean Water-ridges." (See p. 91.)

Mr. Chadwick said, in talking of water-sheds, they were talking of something visible and palpable, the water-shed referring to the whole surface, from the hill top to the valley bottom. As to any other water-sheds, such as had been referred to, that was another thing, and ought to receive another name, because it dealt with something invisible and unknown, and a water-shed in that sense might carry one across the Channel.

Mr. Shelford, C.E., F.G.S., said he was a worker in the field described by Mr. Lucas, but quite independently. Last year, the Metropolitan Board of Works having brought in a Bill for the purpose of supplying water to London from the chalk, it fell to his lot to investigate for them the chalk district to the south and south-east of London, and he desired to bear his testimony to the value of Mr. Lucas's map in that investigation. It was conducted by gauging the springs and streams, by measuring the depths of water in a great number of wells, and by consulting the maps published by Mr. Lucas. The general result shown was that the bed of the chalk dipped towards the Thames, and the subterranean water had a tendency to fall also in that direction. As Mr. Lucas's map showed, there was a great fault which threw up the chalk against the London clay, and so stopped the flow of water in the neighbourhood of Deptford, where the Kent Water-works supply was drawn from, and, further to the west, there was a subterranean anticlinal, which also stopped the water, so that the general trend of the whole water which fell on the chalk to the south and south-east of London, was towards the north, and thence to the east, where it issued into the Thames at or about Gravesend. That fact was further proved by the sections of the River Thames, which showed a certain deepening of the river at that point, which could only be accounted for by the fact that there was a great burst of subterranean water into the river there. Whilst that was the underground condition of things, on the surface it was very different. The River Cray was entirely a chalk river, and the River Darent partly so. There were also other springs, both permanent and temporary, called "bournes," which flowed at different times; and it was quite impossible for anyone, with only a geological map in his hand, to find out what were the water conditions of the district. With the assistance, however, of such a survey as had been carried out with great spirit by Mr. Lucas, there was no doubt that the subterranean water conditions could be much better understood. He also wished to say a word in support of the suggestion made by Captain Galton, that the different authorities who had information at their command should be put into communication with each other. He had lately been to Italy, on an expedition connected with the hydraulics of a great river there, and had access to the Government Department, and had been much pleased to find how elaborate the information was which they possessed. He had with him specimens of the documents and diagrams that were prepared by the Italian Government, which he should be glad to show anyone interested. They showed not only the water line of the river, but the matter in suspension, the temperature of the water, and of the superincumbent air, the rainfall, the flow of the rivers, and other matters. There was no comparison, however, between Italy and England; first, because the Italian rivers run into tideless seas, and the English into tidal, which everyone acquainted with tidal engineering knew meant an enormous difference. Another thing was, that in Italy there were a large number of military and other Government officers who had little or nothing to do, and they had, therefore, better means of getting information with facility than in England. He would venture to suggest that, as a first step, the information which was required should be formulated, and that some society, like the Society of Arts, should put into shape what actually was required, so as to ask the Government for something definite. Even if they were not successful in the demand, if the formula was a good one, it would be adopted by a great many gradually, and would stand or fall upon its merits.

The Chairman next invited discussion on questions connected with the conservancy of rivers.

Mr. Dillon read a portion of his paper "On the Effects of Under and Arterial Drainage on Rivers and Floods." (See p. 97.)

Mr. Lloyd said he had had the honour of giving evidence before the Parliamentary Committee, to the effect that the drainage works on the lands of the upper catchment basin contributed to increase floods. It might be a moot point whether under-drainage did or did not increase floods in a river, and it had been said that by under-drainage you got yesterday's rain and to-day's rain. He did not himself feel confident on that point, but he was confident that surface drainage on the upper part of the catchment basin was certain to contribute to the increase of floods. He could point to open mountain sides where, for centuries past, there never had been any gutters or cuts made, but where, within his own memory, there had been open gutters cut down those mountains on purpose to dry them. It was clearly manifest to any one that, if you provided gutters as water-courses along sides of mountains, the tendency must be to vastly increase the flood within those rivers. He did not believe that the measure proposed by the Government would be the unpopular one some thought; but, whether it was or not, he believed it was a just one.

Mr. Rawlinson, C.B., wished to explain some evidence he gave before the committee on river floods, which he found had been misunderstood by a great many. He stated then broadly, and he now reiterated the statement, namely, that drainage and cultivation had nothing to do with increasing the excessive floods which took place in rivers; and he stated further, that no work of man that had been, or ever would be done, in the shape of drainage or cultivation, would in the slightest degree affect excessive floods. The three elements upon which floods depended were entirely beyond the reach of human interference. There was the salt ocean to be evaporated, the heat of the sun to raise the water, and the atmosphere to convey it away, and to precipitate it. When man could control or modify any or all of these elements, he would have power to modify and control excessive floods, because it was of excessive floods that he wished to speak. There were floods and floods. He should be foolish to say that land drainage and cultivation, and arterial drainage did not let down ordinary water-falls more readily than they came off land without drainage, but those waters did not cause ve floods. They went away, when the river was in moderate flow, peaceably and quietly. A flood was caused in this way. When you had rain on rain, that is water on water, and then, whether you had a surface which had been drained 4ft. or 6ft., and made into the character of a sponge, or the same area as it was before it was drained, in the character of a swamp, when the rain had been continuous, week after week, and the subsoil was saturated up to the surface, and heavy rain continued to fall on that area, whether it was rocky or sandy, or a drained subsoil, it made no difference, as in such excess you got seven-eighths coming down to the river, causing an excessive flood, as such conditions caused it 10,000 years ago; and if the country remained geographically as it was, would cause such area to be flooded 10,000 years hence. There was no fresh water on the surface of the globe, or within the earth's crust, which had not been carried there by the atmosphere. Many persons had, however, a sort of idea that there must be an underground manufactory of water, and they seemed to think that you had only to sink a well deep enough and you would get water. Thousands of pounds had been so wasted in fruitless attempts to get water where it did not exist, because there was no more a general distribution of water in the stratification below the crust of the earth than there was on the surface; and, if he might use a comparison, the subsoil water of the earth might very justly be compared with the surface water; it lay in what may be termed lakes, rivers, ponds, and pools; and as upon the surface the dry area is very much in excess of the wet area, so in the sub-strata of the earth's crust, the dry or waterless areas are very much in excess of water-bearing areas. Again, there was not one square mile of the earth's crust which had not been fissured, having water-tight faults; if it were not so, mining would be almost impossible. The earth's crust is in all places fissured by faults, one portion of the stratification being lifted above the other; it is also interleaved with impervious strata. There are, of course, water-bearing strata, and because you get water by sinking in one place to a certain depth, it did not follow that you would get it a mile away. Then, with regard to the depth at which water was found, it was supposed even by some intelligent people that you had only to go deep enough and you would get more water. But what was experience? Take the deep coal mines which had been sunk in the north of England. There were mines from 1,800 to 2,400 feet. They generally commenced in the magnesian limestone, and to the extent of 600 feet you might have overwhelming volumes of water, which cost great sums of money to tub out, but after getting down to 900 or 1,000 feet you were free from water. The upper portion of the shafts were what was called "tubbed," that is to say, lined with cast iron plates to keep out the water, but when you got down, say 1,000 feet, you had to tap the casing to carry water down, to water the roads, and keep the place in working order. In going through the oolites and mountain limestone, you often met with hot springs, and there you necessarily had an underground substratrum of water, not necessarily in large volumes, but going down in syphon-like fissures, probably 5,000 or 6,000 feet. Those springs almost always occurred in limestone districts. Some philosophers asserted that volcanic action was due to the emission of the ocean into the volcanic region, but he did not believe it. He did not believe that, excepting accidentally, where a volcano might spring out of the depth of the ocean, and the surface might come in contact with the sea, or where it might be immediately on the edge of the sea, and might rupture the earth's crust, that the two were at all connected; as the deep-seated action of a volcano was beyond the reach of any water from the surface of the earth. With regard to river conservancies, it was very important that their areas should be defined, and that the volume of water falling and flowing off should be ascertained, but there were things which must be known beyond these. To uage a river, and to ascertain the area, did not always ive all you required to know, whether you would be afe or not in adopting the area for water supply, if hose facts had only been collected over a brief period. It ould take a century before you could get all the reliable acts that such an area would give you. The rain guage ight also be excessively delusive to the engineer. Water as collected in a rain guage, which was a vitreous substance supposed to store all that fell upon it, but in the alley of the Thames, for instance, where the average as 30 inches, he found this law to prevail, and not nly here, but wherever he had studied the rain guage ables. Take the average over a series of years, and dd one-third, it would give you the maximum, and you deducted one-third it would give you the inimum, and the dry period over the flooded or wet eriod would be about as one to two. But that stimate might also be most fallacious, because it epended how the rain fell. He had known on the east oast twenty months continuously, when no water ould be collected from that surface into a reservoir ade to receive it, and in the height of summer in outh Wales, if 2½ inches, which was a very heavy fall, ame down in a week you would have nothing from the athering ground there. It might go on for the ntire summer, a heavy fall for a week, and then two r three weeks of dry weather; and, therefore, the inimum fall would be reduced again to an item you ad not at all anticipated.

Mr. Chadwick asked Mr. Rawlinson how many intances there were in his experience, of success in deep orings to something like a thousand feet, for supplying ater to towns?

Mr. Rawlinson said he knew very few. There was he Grenelle well, near Paris, which went down about ,800 feet, and brought water up at a temperature of bout 81°. In all these instances, where you went to great depth in the earth's crust, the water which ltered from the surface, and got down there, came in ontact with all the minerals between the surface and he bed in which it lay, and brought some of the salts f those minerals with it to the surface. You might ink a thousand feet, and get water absolutely worthess, as at Rugby, for instance, where they sank a housand feet and got none; they borrowed £6,000 ore to go further, went 1,200 feet, and got brine.

Mr. Homersham said he knew enormous areas of and covered with clay, having a subsoil of chalk, where hat were called "dumb wells," had been sunk hrough the clay into the chalk, and the drainage of the and had been carried into these "dumb wells," and as all absorbed by the chalk beneath. That was still arried on to a large extent in some districts, and he ad found three generations of men who had been ngaged in this occupation. In that case, no doubt the ffect of drainage was not to increase floods, because one of this water would be delivered into the river; went into the chalk at an elevation varying from 500 600 feet above the sea; it went down into and along e great body of the chalk through fissures until it was ischarged into the ocean by subterranean drainage. In his case, surface drainage, instead of having tended make floods in the river, had rather tended to iminish them. There were other localities where rains would increase the flood, because the surface ater would reach the rivers more quickly. With egard to the point mentioned by Mr. Rawlinson, that ou did not get water below a certain depth, that all epended on the strata you were sinking in. He was ld enough to remember when there was a great contest t Liverpool, whether the town should be supplied from e red sandstone or from surface water. After a great eal of contention, it was made to appear that it was ot possible to get water from the red sandstone to a reater amount than one million gallons a day from only ne well; but, not more than two or three years after that, three million gallons from one well only was got without any difficulty, and at the present time some enterprising contractors in Liverpool had sunk a well to a depth of something like 1,400 feet or 1,500 feet, and had got an enormous supply. At present he could not state the exact amount, because the engines and pumps were not got to work.

Mr. Chadwick asked what was the quality?

Mr. Homersham said very good; not more than 14 grains of solid matter per gallon. Much of the water in the red sandstone was of very good quality, and if it were rather hard, it could be softened by Clark's process, and delivered far superior to anything we had in London. Around London there were something like 4,000 square miles of chalk not covered by clay, where all the rain was absorbed as it fell. He could show them 100 square miles of country in one patch where every drop of rain was absorbed as fast as it fell, and never appeared at the surface. It was in circumstances like these, where you had a large area of absorbing country, that you succeeded in getting enormous volumes of subterranean water, and when you did get it, it was worth all the trouble and expense, because as a rule it was wholesome; neither hot in summer nor cold in winter, and did not freeze in the pipes. With regard to surface water, whether it was from Loch Katrine or from rivers, you always found it contaminated with a large amount of living organic matter. No doubt it was sometimes soft, and contained very little mineral matter in solution, but against that must be put the fact that the bottoms of lakes were covered with mud, and all kinds of organic impurities which were taken in solution, the effect being to nourish animalculæ in the water, and the consequence was that although you had it soft, it was not nearly as wholesome as that obtained in the chalk. London was very admirably situated in this respect, and there was not the slightest difficulty in supplying the whole of London with water from subterranean sources. Twenty-five years ago, he sunk a well and made works to supply Charlton and Woolwich; it was then said that you would have water for a short time, and then it would cease, but at the present time, in these the only districts near London where there had been competition in the supply of water for the last 50 years, the Kent Water Company derive all their supply from chalk wells. Ten million gallons were supplied, including Greenwich and Blackheath, and a much larger quantity could be got without difficulty.

Mr. Rawlinson said he was quite sure that Mr. Homersham did not mean to say that all the rain falling on the surface was absorbed, whether on the chalk or anywhere else. The rainfall in the Thames valley had been accurately gauged, as also in the valley of the Lea, and taking the average rainfall of one at 27 inches, and the other at 25 inches, the volume that flowed out of the Thames did not exceed six inches. One-third of it might go in flood, and one-third in perennial springs, but 20 inches absolutely passed back into the atmosphere, re-evaporated, and never appeared in any shape. Again, with regard to the chalk absorbing wells, which Mr. Homersham had mentioned, no doubt that action was taking place artificially as it had been from time immemorial naturally. There were large sand and gravel pockets or pipes in all chalk formations, filled with gravel, like inverted sugar cones, the origin of which was this. The rain-water had fallen on the surface, and pure water being a powerful solvent of lime, it combined with the lime, dissolved it and filtered down, and was carried away in springs. That went on, and the gravel followed it down, and so you had these inverted cone and pipe deposits in the chalk in some instances to great depths, simply shewing the solvent action of the water on the lime.

Mr. Homersham, in explanation, wished to say that he certainly did not mean that all the water which fell was absorbed, because a certain portion went to support vegetation, but none ran off the surface; although the Thames only gave six inches out of 26 inches which fell on the surface, a very large proportion, nearly two-thirds of it was absorbed. It did not evaporate away into the atmosphere as Mr. Rawlinson asserted, for it was by means of artesian wells sunk into the chalk in proper situations that you might get at this water so absorbed.

Mr. Baldwin Latham said he believed he was the only person who had made any series of experiments on the actual amount of water yielded by the chalk formation. He could not now give the exact results, but his guaging , which had been carried on daily during the last four years, on areas in the chalk formation exceeding 90 square miles, showed conclusively that what Mr. Rawlinson had stated was an absolute fact—that the amount of water yielded by the chalk formation depended not so much upon the total amount of rain which fell annually, but on the amount of rain which fell at particular periods of the year. Since the 7th of March this year, the wells throughout the whole of the water-shed of the Wandle and the Hogsmills rivers had absolutely been declining, although we had had a certain amount of rain in the interval. It was impossible for any amount of rain which would fall between now and next November to alter the condition of those wells, which would be one of continual fall. Mr. Lucas' paper, and the diagram that he had exhibited, showed conclusively the value of these hydro-geological observations. It was quite impossible to know whether water was going to be good or abundant in quantity, unless you had this class of survey undertaken. If a man put a well on the top of a hill, with the water flowing both ways from him, he was exactly in the same position as one who was collecting water at the ridge of his house rather than at the eaves; yet such things had been done. Not many miles from London, a waterworks had been established on the very top of the North Downs, and what had been the result? The company had been in such difficulties, that they had never been able, except by borrowing water from other people in the neighbourhood, to supply their district. The quality of water was of equal importance to its volume, and it was quite clear that if you had a town population living in a particular drainage area which had to supply the wells, you might tell what the result of the use of that water supply would be on the health of the population using it, He knew a town very well which drew its water supply out of the chalk, and there was a population of something like 40,000 persons living in the drainage area, which did not much exceed 20 square miles. That town was never free from typhoid fever; but the fever never came except at particular periods, when you got a minimum period of flow. It was a farce to suppose that the springs were flowing with uniform quantity throughout the year. As a general rule, the springs in the chalk were at their highest in the early part of the year, although sometimes they were as late as May or June; but, as a rule, they were always lowest about November. The difference between the maximum quantity flowing off, and the quantity of minimum period, was very great. As a rule, when a large quantity of water was given to the springs, a large quantity flowed away; so that at the minimum periods the difference in different years was not so great. There was likely to be a greater scarcity of water in the chalk at the end of this year than at any time during the last four years, simply from the distribution of the rainfall. One of the most remarkable circumstances with regard to the rainfall, and the yield of springs was this. If there was a good rainfall in the month of December, the springs were sure to be high afterwards; but if you had a short supply in that month, it fixed the character of the springs during the ensuing year. With regard to water from the red sandstone, he understood that the Corporation of Liverpool had abandoned the deep well for procuring additional water supply, because the deep boring, carried to a depth of 1,300 feet, was shown to yield no more water than the shallow borings, and they declined to go to any further expense.

Mr. Homersham said that this was a misapprehension.

Mr. Latham said if he were wrong, he might be corrected, but that was the impression he got when he visited the works, If it could be shown that the wells did yield such a large quantity of water, it must be remembered that the sewers of Liverpool were made in the same rock from which they took their water supply and he had heard that in order to make the sewers as cheap as possible, it used to be the fashion, as described in the "Transactions of the Civil Engineers," to hew out a tunnel in the rock, and put an arch over it to prevent the materials above falling in. Was it suprising, then, that there was no town in England which could compare with Liverpool with regard to its fever or cholera rate, when it drew a large portion of its water supply under such conditions. He quite agreed with every word said by Dr. Tripe in the morning, on the question of drawing water from wells being so exceedingly dangerous. He said you must make the upper part impervious, but experience had now shown that if the whole of the materials were of a porous character, or a porous geological character, no works could be carried out which would shut out the water. That was shown by a case which was well known to Mr. Evans, in which his partner brought an action against the Grand Junction Canal. It was further shown at Croydon, when they lined the wells with iron cylinders, and yet the pumping of the wells affected the sewers. When the ground was perfectly porous from top to bottom, water could not be shut out of a well. Surface water could only be shut out when there was an impervious strata overlying the water-bearing strata. In the generality of cases that was not so. Moreover, water itself was always on the move, and it might come from a contaminated source, and then it was necessary to trace where the water came from. It was quite possible to know which way the water was moving, so that you could get both the quantity and the quality, which it was so desirable every town should have.

Mr. G. J. Symons having stated the substance of the paper written by Mr. John Smyth, said he wished to make one remark on Mr. Rawlinson's statement, that the quantity of water to be obtained at different depths would decrease in proportion to the depth you went down. It so happened that he was a member of the Committee of the British Association charged with determining the rate of increase of temperature underground, and that committee were about to make an experiment in one of the deepest coal mines (2,445 feet deep) alluded to as being so extremely dry. Everything was in the proper train. The engineer had agreed to aid in the experiments, and they were going to bore down from the bottom of the pit, but unfortunately in a neighbouring mine, in the same stratum, at a depth of 1,700 to 1,800 feet, there was such an irruption of water, that the engineer of the mine in which they were going to experiment took fright, and declined to allow a single foot to be bored. Had Mr. Rawlinson not left the room, he should have asked him to give the actual details of the case to which he had referred, where a reservoir had been made, and during twenty months no water flowed into it, because he should like to know where it was, and when it was.

The Chairman said Mr. Brown had left a resolution which he desired to be put to the meeting, which was as follows:—"The incidence of rating for sanitary purposes in rural districts should be reconsidered, and rates for sanitary purposes, including water supply, should, as far as practicable, be made to fall on those who are benefited by the improvements." The words, as he as practicable," he had inserted, because it appeared to him that without those words the resolution was too binding and absolute, but with those words it seemed to indicate a want of elasticity in the present arrangements, which might be remedied. He would move that resolution.

Mr. Cresswell seconded the resolution.

Mr. Lloyd asked if that applied to all sanitary measures, for instance, to the prevention of floods in river valleys? The Legislature had laid down that lands not affected should pay because they contributed to the harm done.

Dr. Tripe asked, in carrying out the Nuisances Removal Act, who would be the persons benefited; those where the nuisance was removed from, or other persons?

The Chairman said, as far as he knew Mr. Brown's views, he did not think they went beyond sewage and water supply.

Mr. Cresswell thought the objection was very well timed, because the resolution might imply even the removal of nuisances; but the words, "in rural districts," were intended to confine the alteration, in the incidence of rating, to rural sanitary districts for sanitary purposes, such as water supply and the disposal of sewage.

The Chairman suggested the following words should be substituted: "The incidence of rating for sanitary purposes in rural districts should be reconsidered. The rates for such sanitary purposes as water supply and sewage, should, as far as practicable, be made to fall on those who benefited by the improvement."

Mr. Alcock said he was not prepared to accept a resolution of that kind, which was an abstract resolution, and which might mean a great deal or nothing at all, according as it might be carried out in detail. If any alteration were to be made in the way suggested by the Bill of Mr. Brown, he thought it would be found almost impracticable on the part of rural sanitary authorities to carry out any improvement, so far as the sewerage and drainage of their districts was concerned. Mr. Brown had put into clauses what he proposed, and those who had seen his Bill might assume that they were pretty well acquainted with his views of the question. He was sorry he was not able to be present when Mr. Brown spoke in the morning; but, as he understood his Bill, it was proposed that, in case of a sanitary authority carrying out works of sewerage, they must levy a separate rate for the sewer, and that applied not only to rural, but also to urban districts, the rate being confined to houses exclusively, and assessable on those only within a certain distance of the drain or sewer. The words the Chairman proposed to insert, "so far as practicable," would over-ride the whole, for he thought the clause was simply impracticable. It was difficult to say within what area or what district the sewer did really confer a benefit. He should maintain that a sewer benefited the entire district, even although a particular householder might think proper to carry out his system of drainage on some principle of his own, and decline to make use of the sewer. Mr. Brown proposed that he should only contribute provided he was within a certain number of feet of the sewer, but there might be one of the houses within that distance, and another just without; the one within might happen not to use the sewer, and the one without might happen to use it; yet Mr. Brown would make the one within, who did not use, contribute, and the one without, who used the sewer, escape, which clearly would be unfair. All those who might use the sewer were the persons directly benefited. But the whole district was indirectly benefited, and ought to contribute; and unless the meeting were prepared to lay down a rule which would have a great tendency to prevent sanitary measures being carried out, it would hesitate before it agreed to any such resolution. The direction of public opinion, as he understood it, was rather to extend the area of rating, and certainly not to limit it in such a way as was now proposed, and, therefore, he hoped the meeting would not assent to the resolution.

Mr. Latham, having had considerable experience in dealing with rural sanitary authorities, was of opinion that if a resolution of this character were passed, such as would ultimately have the effect of altering the incidence of rating, so that it should be entirely confined to clusters of small houses which might require drainage and water supply; all sanitary improvements in rural districts would be at an end. It was quite impossible for these small clusters of houses, inhabited, as a rule, by a class of workmen who were paid the very lowest wages, to pay the cost of such improvements, either through the owners or by the men themselves. Then came the question how came the men to congregate in these clusters and villages? Simply because the agriculturists did not house them on their own farms. If they were all kept upon the soil which they tilled there would be no aggregation in these villages, and nothing like the difficulties, in a sanitary point of view, which now occurred. Men had often to walk three or four miles to their work, and the village was sometimes in the same parish and sometimes not. If the village alone had to bear the expense of sanitary work, the great agricultural district which reaped the benefit of the labour of these men, who lived in these unsanitary villages, would go scot free, whilst the men would still further degenerate and get in a worse state. Seeing that the land only contributed one-fourth of the cost, which appeared to him to be a very fair arrangement, and which, if anything, ought to be increased, and looking at the great benefit it was to the agriculturist to keep his own men in health, just the same as it was to keep his horses or stock in health, he ought to contribute to the cost of these sanitary works. He was well acquainted with the number of the districts where this agricultural element was always cropping out. It was the interest of the farmers, as a rule, to prevent works being carried out, in order to save their own pockets, and almost universally the agricultural element was averse to the expenditure of money in villages for sanitary purposes, and, consequently, very little of such work was done. It was very often in these villages that fever broke out, and was carried into the towns in the milk and other produce, and, therefore, they should be extremely careful before they passed a resolution of this kind.

Mr. Wheeler having had something to do with rural districts, considered that sewering the district was a direct benefit to the whole parish, because if you had typhus or other similar diseases, it meant an increase of the poor rate, the payment of which must fall on the whole of the parish. Where a number of cottages were crowded together, the ordinary plan was that all the drainage should run into an open ditch, and every inhabitant of the parish who passed through the village suffered from the stink; therefore, the sewering of the village was, in this respect also, a direct benefit to the whole of the parish, and the expense should be borne by it. Still some distinction might be made. If he remembered rightly, in the case of Birmingham, an attempt was made to charge the cost of sewering in some way according to the benefit received, and every house which drained into a sewer had a water closet that paid a special rate beyond the ordinary amount. There might be one general rate for construction, and an additional rate for those who had water-closets. A distinction should be drawn between water supply and sewerage. A general system of sewerage was absolutely necessary, but water supply could be provided in rural districts by each house separately from the others by collecting the rainfall, as he had endeavoured to show in the paper he had contributed.

The Chairman said there was a great deal in the remarks made by the last three speakers with which he entirely agreed, but he had a case in his mind which it required some modification of the law to meet. For instance, suppose there was a speculative builder running up a lot of houses in a particular place where he could not get a water supply, and could not drain them for himself, the local authority ought either to have the power of forbidding the houses being inhabited, or to meet the builder by bringing the sewage-works or water supply sufficiently near, and the man who erected those houses was bound to make some fair contribution towards the expense. He did not think the whole parish was bound to bring water, and take means to provide sewerage, for anyone who chose to build a row of houses in the most unlikely place for houses to be built.

Mr. Chadwick said it was sometimes very convenient to levy a very heavy charge, but to relieve the owners and occupiers by spreading it over a wide area, or over a period of years, and this was practicable in a village as well as in a town. For example, you might have drainage of cottages costing £5 each, and when you came to distribute the charge, instead of levying the rate within two or three years, if you spread it over a longer period, the rate would not come to more than 3d. or 4d. per week. There was no doubt that system was applicable, and tables were devised for the purpose by the Home Government Board. That, in his view, would meet the difficulty of adapting the charge to the benefit received.

Mr. Eldred said there might be difficulties with respect to the drainage of a district being included in one local authority. Suppose there were three local authorities, and the one at the outlet of the drainage had done nothing, the centre one had carried out a scheme passed by the Local Government Board, and expended a large sum of money on it. They would have means sufficient for their own property, but by carrying out a system of sewage for the whole district, they would not have enough, and would have to be reconstructed at a considerable expense. He did not think it would be fair in that case to levy the additional rate over the whole district.

Dr. Tripe thought there was a great difficulty in uniting together in one resolution two things entirely incompatible. Drainage was for carrying off water, but water supply was for the bringing of water to the houses. Sewers undoubtedly benefit not merely the place where they are laid, but the whole district, directly or indirectly. The water supply benefits chiefly the parties supplied, and scarcely at all those who do not have the use of it. On sanitary grounds it would be exceedingly dangerous to say that only the persons who were immediately benefited should pay, as it would prevent people draining into the sewer, and induce them to have cesspools wherever they could, and thus injure the neighbourhood, and diminish the general health of the district. It was said they would not be allowed to use cesspools, but in order to bring persons within the provisions of the Act, the houses must be within a certain distance. There were plenty of people now outside the distance who would be only too glad to go to the expense of forming a connection with the drain if they had to pay the rate, but if they were outside the distance, and would therefore escape the rate, they would have cesspools domed over at the top, and open at the bottom, carried into the gravel or other subsoil, which would be their sewer. If a resolution were passed something in this form he should not object to it. "That the water-rate should not fall upon the parties which inhabit the district *pro rata*, but that those who use should pay; and that the expenses originally incurred for water works, or a certain proportion of them, should be in the form of a rate." If something of that sort were done, so that those who had the water paid for it, but a proportion was levied by a rate, it would form some inducement to water companies, or to a sanitary authority to carry out this improvement.

Mr. Cresswell said it was very curious that the difficulties which had been so ably urged were raised by himself that morning. The only difference between his statement of the case and that now heard, was that they were put more forcibly and fully. There could be no doubt that these objections were such, having regard to the sources whence they came, as to demand great consideration, and he was prepared to admit that any resolution coming from that Conference had a weight which should make those who moved and seconded it exceedingly cautious before asking other persons to accede to their views. The experience he had gained over many years in the practical working of sanitation had convinced him that they had overcome all scientific obstacles; that engineers, chemists, analysts, and geologists had supplied them with information, and approved the means whereby, if they had the opportunity, they could remedy the evils which beset the people, but the difficulty they now had to encounter was a moral difficulty—to overcome the inaction of the people, and induce them to bear the expense of the improvement necessary for their welfare. When so eminent an authority as Mr. Brown came forward with a well-considered paper endeavouring to remove an obstacle, the force of which seemed to be appreciated, he conferred on all sanitary reformers a great obligation, and he (the speaker) had ventured to bring the matter before the Conference, so that it might be discussed. He could not help thinking that they had somewhat misunderstood the object of Mr. Brown's measure. He gathered from the remarks made that there was no objection to the proposal, so far as regarded the incidence of the water rate, but as to the question of sewage disposal and sanitary work, it had been urged with great power that everybody, whatever his position might be in a parish, whether a territorial magnate or a humble cottager, was interested in the sanitary improvement of the district, and in the purification of the rivers. He admitted it, and he did not think there would be any reason for exempting anyone from bearing a fair share of that burden. There was the limit in the Act of Parliament, of one-fourth for the agricultural rating, but there were many other cases. The incidence of rating described was not the incidence on the individual only, but on a place or part of a district. The Chairman had called attention many times to a re-arrangement of sanitary areas, and if that measure had been carried, a great deal of work, which Mr. Brown was endeavouring to achieve by this Bill, would have been accomplished. What was wanted was not to lay down an arbitrary law and say that within a certain distance of the sewers people should pay, and at another distance they should not, but to give power to some local authority—County Boards, for instance—to define the area within which the benefits of every sanitary improvement were received, and within which the contributions should be made to defray the expenses. He wanted to see such a state of things as this altered—in one corner of a parish there may be an industrious and prosperous community manufacturing a considerable amount of nuisance, in another part of a parish an outlying district contributing nothing whatever to this nuisance, and yet called upon to contribute towards the expense of removing it. Surely it was a matter of justice that there should be a power, vested by Act of Parliament, in some central authority, to relieve that particular part of the parish of the burden of contributing to the removal of the evil, for which it was in no way responsible. In that respect Mr. Brown's Bill would be found to be a great advantage. In reply to Mr. Alcock's observations, he would call attention to Mr. Brown's paper, where he showed that, within a certain distance, all residents were obliged to use the drains, and it was in the power of the Local Government Board to compel them to do so. If a man was 200 feet away he was not compellable, and he very much doubted whether that should not be extended to 200 yards. But it met Mr. Alcock's objection to say that, according to Mr. Brown's Bill, those only would have to pay who were within the distance, and actually drained into the sewer to be constructed. He thought there was a great deal in the argument as to the direct or indirect, benefit conferred on everybody in the district by a work of sanitary reform, and he should be quite agreeable, if the chairman agreed with him, to modify the terms of the resolution in that respect. But Mr. Brown not being present, he had felt it his duty to defend his proposition, and certainly thought, with regard to the water rate, that some alteration in the incidence of taxation was desirable.

Dr. Yeld thought, by passing the resolution, they would be practically affirming the principle of Mr. Brown's Bill, and before they were called upon to do that, he thought they ought to have an opportunity of carefully going through the Bill, and considering the whole of the clauses. As he said before, it not only bore on rural but urban sanitary authorities, and although this resolution only applied to rural authorities, still there was no doubt an argument might be raised, that if it were good for rural sanitary authorities it was equally good with regard to urban sanitary authorities. The nature of the Bill, which related to the incidence of taxation, laid it down that a separate sewer rate should be levied, and if it went beyond 1s. 6d. in the £, any excess should be levied on the general district rate. It was very questionable whether the clause was workable, and he suggested that it would be better to confine the resolution to water supply only.

Mr. James Lemon hoped the resolution would be withdrawn as far as regarded sewerage, for if it were adopted and carried out, he thought there would be very few drainage schemes carried out at all. Everyone had an interest in the health of a town. If the rate were to be levied on the small area directly benefited, it would be so heavy in many cases that they would not have any rural authority able to carry out the scheme. Only within a few weeks ago, he knew of a case where pressure had been put upon the Local Government Board to cut out a certain portion of a district, proposed to be drained, on the ground that they did not want it, and could do without it, because they had cesspools in the chalk. No doubt they could do without it, but it was a very bad precedent if they were allowed to escape from the fair charges they ought to bear. If the resolution passed it would be the most retrograde step the Congress had ever made.

Mr. Chadwick said a statement as to the distribution of the charges that were said to be so frightful on the people, would be found in his paper showing that 3½d. per week, or one halfpenny per day, would suffice for sanitary improvements.

Mr. Rogers Field, as an engineer who had had considerable experience, especially in connection with drainage areas, wished to fully support what Mr. Latham and Mr. Lemon had said. People would object to drainage, and would continue to use cesspools, if by so doing they could avoid a rate. It would be a decidedly retrograde step if such a resolution were passed.

The Chairman said he had arrived at the conclusion that the best course would be to withdraw the resolution. He was under the impression that the matter had been fully discussed on Mr. Brown's paper, and that the resolution which he left behind was intended to be the record of general approval. For that reason he moved it, and Mr. Cresswell seconded it. He was not prepared to say that there was not a case for some modification of the law, because he thought they had not arrived at the ultimatum in arrangements for the creation of a special drainage area. It seemed to him that Mr. Brown had hit an imperfection, and, so far as he had followed his Bill, the means he suggested were of the right kind. Still there was great weight to be attached to the arguments advanced by several gentlemen well entitled to speak, particularly the objection to giving general approval to a Bill of this kind, on which the clauses had not been discussed *seriatim*. There was also great weight in the view that the function of the Conference was not so much to differentiate between special proposals, as to lay down particular principles, and, above all, to keep before the public constantly the idea of private sacrifice for the sake of public health. In his opinion, those arguments were quite conclusive against a resolution so vaguely drawn as that was, in the absence of that complete understanding which he had assumed to have been arrived at previously. He had sketched out something which more nearly expressed his own views, which he would not propose for adoption, but would read, to show what was in his mind. His view was, that where, in a rural district, either a landowner or a speculative builder erected houses where there was no water or sewage, the local authority ought to make the houses healthy, and his point of view was to increase the power of the local authority, and by no means to increase the exemption. What he had drawn out was as follows:—"That the incidence of rating for sanitary purposes in rural districts requires reconsideration, and that legislative provision should be made enabling local authorities to charge a greater proportion than is now charged of the cost of new sewage and water supply works, erected especially for the benefit of a limited number of dwellings, and necessary for their healthy occupation, on the owners and occupiers thereof." He thought the best course would be to withdraw Mr. Brown's resolution, but in so doing he wished it to be understood that did not imply an expression of any opinion unfavourable to the views Mr. Brown had propounded in the morning.

Dr. Tripe said he should have been happy to propose the resolution read by the Chairman, which only referred to water supply; but he most distinctly spoke against Mr. Brown's resolution in his presence in the morning, and he was quite sure the majority of the meeting held opinions similar, to a great extent, to those entertained by Mr. Latham, Mr. Field, and himself.

Mr. North thought the resolution was very properly withdrawn, and that it had better rest as it was, without any expression of opinion.

The Chairman said that was his view. He was only anxious that, as a consequence of this discussion, it should not go forth as an unfavourable conclusion with respect to Mr. Brown's paper.

Mr. Latham said his view was that it would be extremely dangerous to pass any resolution which would seem to be of a retrograde sanitary character. He did not know what the provisions of the Bill were, but he presumed the resolution was really in agreement with what he proposed in his Bill. Individually, he felt that if a resolution of that kind were adopted, it would do harm rather than good.

Lord Alfred Churchill moved the following resolution:—"That this Conference wishes to express its entire satisfaction at the action taken by H.R.H. the Prince of Wales, President of the Society, in applying to the Government for the appointment of a Royal Commission to inquire into the subject of a national water supply, and it earnestly hopes the Government will take steps without delay to carry into effect the resolution passed at last year's Conference."

Captain Douglas Galton seconded the resolution, which was carried unanimously.

The Conference then adjourned till the following morning.

Mr. J. Clarke Hawkshaw was unable to attend the Conference, but wrote as follows:—I do not think that my paper on "River Conservancy" calls for any further remarks on my part. I may, however, state that Rhineland, of which I have described the drainage administration, is a good representation of other drainage districts in Holland. If I had been able to be present to-day, I should have wished to make some observations on one point in the River Conservancy Bill, and as I think it an important point, I will give my observations on it as briefly as possible. Three descriptions of land are defined in the Bill, flood-lands, intermediate lands, and uplands. Flood lands are defined as lands "liable to floods;" I think they ought to be described as lands lying below the flood level. With the definition as it stands, endless disputes will arise as to what lands are liable to floods, as to whether lands that were liable to floods, but are not so now, should be called flood lands, &c. With the definition I suggest, a line can be put on the survey of the district, marking the flood level, and all lands within it will be flood lands. There is no difficulty in doing this; it has been done for some districts, and it settles the matter once for all. Intermediate lands are defined as lands "draining by subsoil drainage." I thinks the words "subsoil drainage" ought not to appear in the Bill at all, not because I agree with those who say the water flows faster and more copiously off undrained clay lands than off subsoil drained clay lands; on the contrary, I think that much of the water that falls on undrained clay land never flows off at all. It stands in holes and hollows, and is absorbed by the clay in a great measure, and finally leaves the land by evaporation. At a meeting of this Society, in 1855, Mr. Bailey Denton said that deep drains generally begin to run before shallow drains, that they invariably run as soon, and more copiously than shallow drains, and that they continue to run long after shallow drains have ceased to run. I object to the words, because I think they admit a wrong principle of taxation. The rivers of a district form the common channels by which all the water flowing from all the land is conveyed away; and, therefore, all the land ought to be taxed, to ensure the water passing away in those channels without causing loss by floods, or by danger of floods to the lands on the river banks, and the tax for this purpose should be at the same rate for all lands. But as some lands will immediately benefit by the works, that must be carried out to ensure this immunity from floods, they should be taxed at a higher rate. If you once begin to tax lands at an increased rate, because they do something to get rid of their water more rapidly and effectually, why should you stop at subsoil drained lands. If a ditch is dug, if a watercourse is straightened, it has the same effect as subsoil drainage. There is a class of lands which might properly be called intermediate lands, and be taxed at a different rate to the other classes, I refer to land lying not much above the flood level. It can be defined by a contour line on the survey of a district, in the same manner as the flood lands; this has been done for some districts. On the Thames valley drainage plans such a line is shown, 5 feet above the flood line; on some of the plans of districts in Lincolnshire, a line is shown 2 feet above the flood line. The lands lying between such a line and the margin of the flood lands, might properly be described as intermediate lands, all higher lands would be uplands. If the River Conservancy Bill passes the House of Commons, I hope it will not be without some alteration having been made in the definitions of the different kinds of lands. I am sure they will give rise to difficulties and delay as they at present stand.

Proceedings of the second day, Friday, May 16th, the Right Hon. JAMES STANSFELD, M.P., in the chair.

The Chairman, in opening the Conference, said the first subject was—"The evils of impurity consequent on the connection of the water supply with sewage."

Dr. Thorne Thorne then read his paper, "The Recent Outbreak of Enteric Fever at Caterham" (see p. 117), and also added various other examples, showing the connection of outbreaks of enteric fever with polluted water. He also wished to add a word with regard to what might be supposed to be a special danger attaching to large water services. Of course, when such mischief as he had referred to occurred in connection with large waterworks having large areas of supply, it caused widespread disease; but he was convinced that, for every 100 cases of typhoid fever thus produced, the number resulting from the contamination of shallow wells sunk in filth-sodden soils was a thousandfold. Another important point was, that the mischief resulting in the former cases was so easily capable of remedy, whereas the only remedy in the case of a polluted shallow well was to clean it out, and that was utterly useless when the contamination was washed in from the soil in which it was sunk. He thought that the extension of large public works for water supply must be looked on as the most certain means of eradicating an evil which, unfortunately, had hitherto caused, year by year, from 70,000 to 100,000 cases of preventable disease.

Mr. Baldwin Latham, C.E., asked if Dr. Thorne could give any information as to the quality of water taken from this well which was probably mixed with the typhoid poison.

A Member asked how long the elements of disease remained in the water, from the first spread of the disease until it passed away?

Dr. Thorne said he could not satisfactorily answer Mr Latham's question. Owing to the construction of the adit the water became turbid, and, therefore, it was as much as possible pumped to waste to diminish the turbidity, and thus he was unable to ascertain the extent of dilution. There was, however, considerable probability that the extremely mild nature of the disease was due to the enormously diluted state of the poison. It several times happened that mild outbreaks of enteric fever had occurred in connection with a largely diluted state of the poison, but the extent of the dilution he could not say. In the first place, one would have to know the amount of evacuations which found its way into the well water, and this he had no means of ascertaining. The other question was also very obscure, and gave him a great deal of difficulty. He induced the authorities to issue notices, cautioning the people against using the water, and having done that, they naturally came to him again and asked when he would give them leave to use the water. It placed him in a rather difficult position, owing to the imperfect knowledge we have as to the nature of the poison of typhoid fever and the extent to which it would go on developing itself. Circumstances of temperature and humidity, and so on, must have been, to a certain extent, favourable to its development in this case, but he could not form any idea as to the limit of infection. When he came to possess all the facts, he had a strong impression that before the notice was issued, the poison had very possibly been pumped out.

Mr. H. Masters said he had understood Dr. Thorne to say that in one case sewage found its way into the water mains by the junction of the iron pipes. Could he give any further information about that?

Dr. Thorne said, in the case referred to—that of Over Darwen—the sewage passed along a stone sewer up to a certain point, and when that came into proximity with the water conduit, an iron pipe was carefully laid across to prevent contamination; but owing to a leakage which had taken place from the stone sewer higher up, a cesspool was formed by the side of the water conduit. The iron pipe itself did not leak, but the sewage escaped at the point of junction between it and the stone sewer.

Dr. Seaton (Nottingham) asked what was the chemical state of the Caterham water with regard to purity?

Dr. Thorne said that was another very difficult question, and he had specially avoided having the water analysed. His own impression was, that you might have taken 100 samples and never found any evidence of specifically diseased matter in it; but in the one hundred and first you might have discovered it. That alone would account for the immunity of a large number of people who were habitually using the water. He did not like to speak on the chemical point, but he did not imagine any chemist would say he could have told whether the poison of typhoid fever was in the water in an infinitesimal quantity. It was very probable that, from beginning to end, the Caterham water would have given very good chemical results.

Dr. Seaton said he fully anticipated that answer. Whenever the question of possible pollution of water with the specific poison of enteric fever was raised, they were frequently met with the insufficient reply that the water yielded good results when analysed.

Mr. Birkett asked if the incrustation of iron pipes, as tending to cause pollution of water, had engaged the attention of Dr. Thorne at Caterham. He had had some papers printed, showing the effects of hard and soft water on iron pipes, and he thought that would be found to be the principal cause of disease.

Dr. Thorne said he had understood, from a remark made the previous day, that the suction of foul matter into the mains would be necessary before it could cling to any such incrustation in iron pipes, and so give rise to epidemics.

Mr Birkett said this incrustation would take place, even with a constant supply. When there was an intermittent supply of water there was sufficient space for gases to be generated, and the first water which passed through naturally got impregnated with impure gas, and disease resulted.

Dr. Thorne remarked that this presupposed that filth got into the mains and was capable of generating foul gas. At Caterham he did not think it was so, besides which the supply was not intermittent.

Mr. Colebrook (Reading) asked if any surface filtration was practised with the Caterham water, or in any of the other cases mentioned by Dr. Thorne; also, if in his opinion, the contaminating matter could have been removed by that process?

Dr. Therne said the Caterham water was not filtered. It was, as a rule, subjected to Clarke's process, but, owing to some works then going on, the process was not always carried out. In the Lewes case the water was not filtered, but if it had been it would have made no difference, because the contamination took place after the water was in the mains. He could not speak positively with regard to the other question, but he felt that filtration was, as a rule, at the best mechanical, and they had every reason to believe that the particles which gave rise to enteric fever would not be removed by mechanical filtration.

Captain Douglas Galton, C.B., F.R.S., asked whether the water was subjected to filtration in the houses.

Dr. Thorne said it was in some instances, and some not.

Dr. Vacher remarked that, in speaking of the cases in that epidemic being singularly light, Dr. Thorne said he thought that might be due to the poison being received in a very dilute form. He wished to ask if he had any warrant for that belief? The poison being particulate, he believed that when it was very dilute it diminished the chance of a person taking the disease at all; but when he had once received the seeds of this disease, it had then the power to fructify and multiply so much, that probably, if the water was very dilute, and delivered to 100 people, 99 would not have the disease at all, but the one subject who would take it would have it in as bad a form as if he took several germs instead of one.

Dr. Thorne said he could only answer the question very generally, by saying that he believed, in several instances where the dilution of the poison had been obviously very large, the mortality of the epidemic had been extremely small. Taking the Caterham and Guildford cases especially, the mortality was very slight. He was under the impression that if we received into our systems a definite quantity of a growth, capable of developing up to a certain point, the chances were, that if we received ten times that amount, the disease would be much more severe.

The Chairman said he doubted the advisability of entering on a discussion of this purely medical point; they were assembled as sanitarians, not as medical men, and he presumed they were all satisfied that, however diluted the poison might be, it ought to be kept out of the water.

Mr. Lucas asked if Dr. Thorne had ascertained whether the deep borings, put down through the chalk into the lower greensand, yielded any water; and inasmuch as the adit was constructed for the purpose of passing the water into the well out of which the Caterham Company pumped, whether he had ascertained at what date the water from the lower greensand was supplied to the Caterham Company's well. He wished to know whether he had thoroughly sifted the question, so as to satisfy himself that the introduction of this new water had nothing to do with the outbreak of the disease, because he thought the evidence with regard to the evacuations was somewhat weak, and, to say the best of it, he thought it was a case of not proven.

Dr. Thorne said the information he received from the Company was that the lower greensand was reached at a date when the cause of the epidemic had already ceased to be operative.

Mr Ernest Hart then read his paper, "Epidemics produced by Polluted Water Supply." (See p. 119.)

Mr. Cresswell said he could give a piece of information to the Congress which he thought would be satisfactory. A very important question had been asked of Dr. Thorne, whether he had examined into the chemical condition of the water in the Caterham case—whether, in fact, chemistry could have discovered any trace of infection. He, however, had very wisely abstained from having the matter chemically investigated. As a mere matter of legal procedure, he wished to inform the Congress that the Courts of Law, in the famous case known as the Cockermouth case, had decided that it was not at all necessary to prove the existence of a legal nuisance in the water alleged to be contaminated. It was quite sufficient to prove that there was a potentiality of contamination, that water, in fact, had been allowed to flow from sewers into a river, and chemical demonstration of the existence of pollution at a given point was unnecessary, and necessary to justify an injunction being granted to prevent a violation of sanitary law. Cockermouth drained into a river known as the Derwent, and the people of Workington, eight miles below, complained that they were being poisoned, and sought to restrain the pollution of the river. The argument on the part of Cockermouth was this, prove that we have created a nuisance by the existence of a nuisance at Workington, from whence you draw your water supply. They called in Dr. Frankland, on behalf of Workington, and he stated to the Court that it was impossible to discover, by chemical analysis, any traces of pollution in the water; but he added this very pregnant statement, that he himself was satisfied of the existence of pollution, although it might be impossible by chemical analysis to detect the germs. The Master of the Rolls, whom they knew to be a learned and energetic judge, by no means trammelled by antiquated traditions, decided that, inasmuch as the Legislature had satisfied itself that it was an improper and unjustifiable act to pollute water by sewage, he would not require absolute legal evidence to justify the intervention of the Court.

Dr. Seaton said his object in asking the question of Dr. Thorne had an important bearing on an outbreak of enteric fever, which occurred eight years ago in Radford, a suburb of Nottingham, and which had been investigated by him. The district was partly supplied with water from a well sunk in the bunter beds of the new red sandstone, in a populous part of the town, and which, on chemical analysis, presented very fair results. Nevertheless, the facts pointed strongly to a connection between the water supply and the spread of the disease, and this was the more probable on account of the position of the well and its liability to occasional contamination. Dr. Thorne's conclusions were, that all possible sources of excremental contamination in the vicinity of water sources should be strictly inquired into and rigidly dealt with. In that particular instance the supply of water was in the hands of a private company, and although it was of the utmost consequence that the supply should be investigated in the fullest possible manner, the company objected to giving the opportunity of so doing, on the ground that their own adviser (an eminent chemist) had pronounced the sample he examined to be good. He had himself experienced much difficulty in impressing upon people the importance of not resting content with chemical analysis alone in the matter of water, and the need of looking narrowly to possible causes of excremental contamination, it being necessary to regard all such contaminations as potentially that of enteric fever.

Mr. Lewis Olrick said the Conference met for the purpose of improving the public health, and one would naturally infer that the public would be most interested in the subject, but it was nothing of the sort. He had himself, simply as matter of precaution, adopted means for purifying the water used in his own house. Of course in the cases mentioned by Dr. Thorne, Mr. Hart, and Mr. Latham, no filters in the world would purify the water, but the difficulty might be met by boiling it. Unfortunately, the public would not take the trouble to protect their own health. He did not speak merely of poor persons, but those comfortably off would take great care to provide an ample supply of wines and spirits, but if you asked them to spend £3 or £4 for the purpose of purifying their water, they would not do it. He hoped one result of this Congress would be to teach the public a lesson, that there was an immense danger in not purifying drinking water, and if they did not take heed of the warning they must put up with the consequences.

Mr. Baldwin Latham said they were all much indebted to Dr. Thorne for his very valuable paper, and although this outbreak had been the means of inflicting so much misery on many, yet the lessons to be drawn from it would be of great use in the future. He was prepared to believe that very few outbreaks of typhoid occurred except under the influence of impure water, but he could not quite agree with the conclusions arrived at by Mr. Hart, that there were other modes of impurity by which water might be polluted: he thought it very doubtful if any aerial impurity could be absorbed which would be the cause of typhoid. If Mr. Hart had carefully considered the case at Croydon with respect to an intermittent supply and the impurities being drawn in, he would have found, from Dr. Buchanan's return, that in 1875, in the months of June and July when there was the greatest demand for water, and the greatest intermittency in consequence of not being able to supply the demand, they were the two months freest from fever. Again, with regard to the 1875 outbreak in the Friends' School at Croydon, the boys' wards were supplied direct from the mains, but the girls were supplied through the intervention of an open cistern in the roof. There was a great outbreak of fever on the boys' side, but not a single case on the girls' side. There the intervention of a cistern seemed to have been a preventive. The late Dr. Letheby carefully inquired into that outbreak, and recommended the authorities to introduce similar fittings into the boys' side of the school. Again, in 1875 alone, there were something like 1,400 cases of fever in Croydon, and the whole of the dejecta from those patients was passed into the sewers and then on to the irrigation farm. Between the irrigation farm and the River Wandle was situated the very populous district in Wallington, which drew its water supply from wells, so that they got little or nothing but the percolation of this sewage farm; yet it was a singular fact that, in 1875, there was not a single case of enteric fever in any part of the district. There you could trace the underground water on to the farm and through wells down to the River Wandle, and yet under those conditions, it showed that the effects of exposure of the water, as in irrigation, entirely destroyed the poison of this particular disease. He had charge of the whole of the district for sewerage purposes for some miles round the Croydon Irrigation Works, and the sanitary authority had been most anxious as to the health of this district. For many years past it had been found that the whole of the valley of the River Wandle, starting from Croydon Sewage Farm, and passing down to Wandsworth, was remarkably free from enteric fever. It was ascertained by measurement of the wells in that district that they never fluctuated, the soil was rather porous, and there were 36 mills on the River Wandle, which dammed up the water, so that the water level of the subsoil varied but an inch or two from one year's end to another. That meant that the subsoil must always have in it a certain amount of water, and there you came to the question of dilution. Since 1875, although there had been no intermittent water supply whatever in Croydon, yet the amount of fever was not got rid of. The conditions were these. The moment the water got to a remarkably low level, on the very first instance of the rise an outbreak of fever occurred; and from having himself made four or five experimental wells, where he had now had for two years self-recording apparatus at work, recording every fluctuation in the subsoil water, he could show that it was due to the fact that when the springs got to the very lowest they began to fill up in the lower parts of the districts before they did in the upper portion, and consequently surface impurities were carried down when the springs were low, just at the time the springs again began to rise. That was corroborative of the results obtained in Germany by Professor Pettenkofer, who showed that enteric fever, and even cholera, was always coincident with the lowest levels of subsoil water. It was true that the greatest outbreaks of fever always occurred after the driest periods. Dry years were invariably fever years. If we were now to have a long dry period, very shortly after the first shower of rain in most of the villages supplied by local wells, there would probably be outbreaks of enteric fever. He had a strong impression that the influence of light had a powerful effect in destroying whatever might be the poison of enteric fever and some other diseases. Pollution under the conditions darkness, such as getting directly into the water ains, as happened some years ago at Ely, or into the round water, was the most dangerous. There were a eat many cases which all showed that underground ntamination was far more dangerous than above round. A well known case was that in the first olera outbreak, where it was shown that at Wolverampton the place was so attacked that the people tually camped outside the town, the sewage all passed to the River Tame, which flowed down an open annel for several miles, and the water was pumped r the supply of Birmingham; yet there was only one se of cholera in Birmingham, and that was reported be an infected case. It did not matter whether ey had to deal with germs or specific poisons, long as it was known what the conditions were hich caused disease, and it all came back to the queson of fæcal pollution of water. Guard the water from ollution, and you were safe from many diseases.

Mr. Alcock said there was no doubt a deficiency in he powers of sanitary authorities, in some cases, as as shown in the case mentioned by Dr. Seaton, where he supply of water from a deep well was apparently ure, and being in the hands of a private company, hey objected to its being inquired into, because they ad a report from their own chemist that it was ure. It was this difficulty he wished to draw attenion to. When the supply was in the hands of a private ompany, how were the sanitary authorities able to leal with it, when, as in that case, the water might be hemically pure, and yet the sanitary authority might e perfectly satisfied that it was polluted from sewage, r other deleterious matter? In the neighbourhood of Sutherland, where the water supply was certainly pure, nd for drinking purposes admirable, they had found very great difficulties in many ways; first, in enforcing he supply of water, and, next, in consequence of its being entirely in the hands of a company, of detecting mpurities should they exist. One of the first necessiies in connection with water supply was, that it should e taken out of the hands of private companies, and vested in sanitary authorities, who otherwise were almost powerless, unless they could show by chemical nalysis that the water was impure. It was very difficult to trace the impurities, and having traced them probably to their own satisfaction, it would be very much more difficult to enforce any improvement upon a private company. Many sanitary authorities would ike to obtain power to transfer the water supply to heir own hands, but when they had the experience of he Stockton and Middlesboro' Bill, which only passed a session or two ago, and the frightful expense it entailed o enter into a Parliamentary contest with a private company, they might well shrink, as they did at Sunderland, from such a course, although they would be most happy to take over the water supply, paying the shareholders a liberal compensation for their property.

Dr. Thorne regretted that he had not made fuller eference to the action of the Caterham Water Company, because, although he fully agreed with the last peaker in many points, he thought the difficulties experienced in dealing with private companies were certainly not universal. The moment he suggested to the Caterham Water Company there was a possibility that heir water was producing mischief, they told him that every information and assistance by their staff was absolutely at his disposal, and the Chairman himself not only helped him officially, but told off one of his engineering clerks to go with him and work up the subject. In fact, without the company's help, he should have had great difficulty in dealing with the special immunity of Warlingham. The company also adopted every single recommendation he could suggest, after ascertaining the cause of the epidemic; the wells were saturated with a strong solution of chloride of lime, and they pumped the water to waste for about three weeks, in order to get rid of all water which could have been contaminated.

Mr. Mackinnon said it was impossible to overrate the importance of the paper they had heard that morning, and he could support the conclusions arrived at by his own experience of many years in Monte Video. The houses there were all flat-roofed; the rain-water was collected from those house-tops, and carried by pipes to a reservoir under the pavement in the centre of the courtyard. As they all knew, cats were very fond of taking the air on the house-tops, and consequently there was a rapid accumulation of their excreta which was carried down with the rain to these wells. The water was also contaminated from the cesspools, which were attached to each house; and, as they knew, human urine had a powerful effect in dissolving lime and cement, and consequently these liquids very easily found their way into the reservoirs. He was Director-General of Public Works, but had never found one reservoir where the water was not contaminated. The result was, that diseases were very rife. A system of sewage had been carried out, and also a supply of water by a company, but the public were very loth to take advantage of these appliances until a very severe outbreak of cholera, yellow fever, and typhoid made them think whether they had been doing right. He hoped the time would come when the Government of Uraguay would insist on every inhabitant connecting his drains with the sewers, and consuming water supplied by the company, and ordering the closing up of each reservoir and cesspool attached to each house.

Dr. Ward said that very often medical officers in the country had opportunities of pursuing investigations into the causes of diseases which those in towns had not. In the district it had been his privilege to administer for the last few months, there had been peculiar facilities for studying typhoid fever. His district was in West Cumberland, commencing with Keswick, and going down to the seaboard. There were very few cases at Keswick where they had pure water; at Cockermouth there were more cases where the water was river water, and, to some extent, contaminated with land drainage. At Workington, during the last winter there had been 50 or 60 cases of typhoid, some very severe, but others milder. The intensity of the fever was not altogether owing to the impurity of the water, but also to the contamination of the house atmosphere from sewer gas. He had investigated many cases, and always found that where they were most severe, there had been sewer gas present in the house. He would not say that this was an exciting cause, but it was certainly a predisposing cause of typhoid fever, which was apt to be overlooked. The conclusion he came to was that impure air was not only largely the cause of zymotic diseases, but also of a large amount of local diseases, such as inflammation of the lungs, and of the brain, which he had clearly traced to the pollution of the atmosphere.

Mr. Maxwell said the lessons they were daily getting on minute contamination could hardly be too strongly impressed on the public mind, and what had been heard that morning would go very far to do away with the idea that a chemical analysis was at all times a test of pure water. The question of constant supply was one which ought to be considered in reference to these particular contaminations, and he had no doubt that contamination did get into the pipes by an intermittent supply, as when it was cut off daily, which was the practice in London, or when the pipe-layers were at work in the streets. As a rule, all taps were left open for the supply to come on again, and the consequence was, there was a natural suction into a great many of them, which absorbed the air from the vicinity. In the case of water-closets this had a very detrimental influence, because many of those closets were still constructed with the water service communicating direct to the soil-pan. It ought to be a rule that no water-closet should be constructed without the supply being taken from a separate cistern. He was much struck with the remarks of Mr. Latham about exposure to air and light. He was connected with works where the supply was from artesian wells, and some people wanted them to pump direct from the wells without the intervention of any reservoir. That they could not do, because the well did not yield sufficient during the day for the supply, and they were compelled to store a certain quantity; but the question was often asked—Was the water injured or not by being brought up from the chalk and exposed to the light. His own impression was, it was not; but it was a point upon which he should be glad to have further information.

The Mayor of Oldham (Mr. Hamilton) said he had listened to the various speakers with very great interest and profit to himself. He might point out that there was one source of contamination which had not yet been touched upon, but which was very general throughout the agricultural districts. In all large farms it was usual to have what was called a straw-yard, where cattle were impounded day and night, and their excreta was collected generally for twelve months, when it was cleared, out and fresh straw put down for the ensuing year. Almost in every case the straw-yard extended near the farm house kitchen door, and the well for the supply of the house and farm-yard was between the two, a portion of the liquid manure thus found its way into the well, and there could be no doubt an immense deal of contamination occurred. He was a frequent visitor to many of our largest agricultural counties, and after hearing what he had that day respecting impure water being the sole cause of typhoid fever, he must say he was thankful he was still alive. He quite agreed with those who affirmed that a good and pure supply of water could be found above and under ground upon nearly all the farms in England, and he was certain that every rural parish could find within itself good and pure water sufficient for its requirements. He trusted that at next year's Conference a paper would be produced on this subject.

Mr. S. W. North (York) wished to ask Dr. Thorne if there was any evidence, and if any what, of the multiplication of the elements of typhoid fever outside the body. There was no doubt that infected material conveyed the disease to others, but there was the greatest difficulty in persuading the general public, and even sanitary authorities, that 2 or 3 ozs. of infected material poured into many million gallons of water, could propagate the disease amongst the general inhabitants using the water. He thought himself that sanitary authorities and the general public were to some extent right, and that, if typhoid fever were propagated by such minute infections of water, we should none of us escape. He could only say he should scarcely dare taste water again if he thought such a thing probable, because he could not see how you could get water which might not be more or less contaminated in that way. In saying this, he said it with the full conviction that, in tracing the origin of typhoid fever to the contamination of water in some way, we had got on the right track; all he wanted to say was, that they should not commit themselves to any conclusions which were not ascertained facts. There was in the general public, although not well informed, a pretty strong logical mind, and there was considerable difficulty in persuading them that these very minute causes had the widely operative influences which some sanitary authorities supposed. He, therefore, wished to ask Dr. Thorne the question he had stated.

Dr. Thorne said a complete answer to the question involved such an immense amount of information that he hardly liked to enter upon it. He did not feel himself capable of doing it safely from a pathological point of view, but the facts certainly bore out the view he had expressed, and not only so, but there was ample proof that minute quantities of poison had produced these results. For instance, take the Lewes outbreak; it was clearly due to minute particles of typhoid excreta which were drawn from certainly not more than a dozen closet pans in that town into the mains. Whilst those particles were being drawn into the mains, the disease was rapidly progressing, and the moment a constant service was put on, which prevented that suction from taking place, the disease stopped.

Mr. S. W. North said he did not dispute the general inference from the published information, and he would save the time of the Conference. He wished to confine himself to the question whether there was any evidence of multiplication of disease germs outside the body.

Dr. Thorne said that in an allied disease the specific germs had been isolated, but he had never seen a typhoid germ, and therefore could not say there was any visible evidence. He knew himself there were such specific germs, but he did not think he could prove it to any one, apart from the general inference to be drawn from epidemics.

Mr. Ernest Hart moved the following resolution:— "That since a comparatively minute quantity of the poison contained in the evacuations of the patients of enteric fever may, it is believed, when subjected to conditions favourable to the development of that poison, lead to the specific infection of very large volumes of water to which it has gained access, all sources of excremental contamination in the vicinity of water sources should be rigidly dealt with during their construction or repair, and in their use." He thought the information contained in Dr. Thorne's paper, and his own abstracts, would amply justify the Conference in passing such a resolution. It might, of course, be open to doubt, and it was open to further research, whether, and in what way, the specific poison of typhoid fever multiplied out of the body. That was a question of minute pathological investigation, which was open to this preliminary difficulty, that, as Dr. Thorne had said, they had not yet isolated the particular contagium of typhoid fever in such a manner as to be able to experiment with it by culture. On the other hand, all the facts, irrespective of any pathological theory, pointed irresistably to that conclusion. It has proved, as a matter of fact, that a particular source of water supply being infected, an enormous number of persons had suffered from typhoid fever so infiltrated. Not only were there now stated a number of facts which most minutely investigated, bore that interpretation, but they also found another kind of facts, that by cutting off the source of contagion you immediately arrested the epidemic, and you might predict with certainty that if at any moment such contagium did pass into water, a large number of people would be so poisoned. He remembered very well in the last cholera epidemic, which occurred in the East-end of London—which was a sudden explosion, so to speak—he then said to Mr. J. N. Radcliffe, who had since become a Government inspector, that all analogy pointed to the fact that an outbreak of this sort must be caused by contamination of the local water supply, and he commissioned him to make an inquiry. All the facts appeared to be against it; but Mr. Radcliffe, following out the various clues, traced it to the East London Waterworks, and it was found that on a particular day the East London Company had used the water from a particular reservoir, and the water in that reservoir had been contaminated by the excreta of a person who had come to Southampton with the cholera, and had come from there to the River Lea, and that the one individual had brought Asiatic cholera to the banks of the Lea, and the dejecta of that one person sufficed to cause the last and most severe limited outbreak of cholera in this country—he trusted he might say, owing to the influmation now obtained, the last outbreak which ever would occur in this country—because he did believe that, in consequence of the precise manner in which enteric fever and cholera had now been traced to polluted water, by adopting such precautions as the resolution pointed to, they might prevent any outbreak of Asiatic cholera in an epidemic form, and also prevent the sporadic, endemic, or epidemic outbreaks, of enteric fever.

Mr. Cresswell seconded the resolution. The first reason why he supported it was, that it would enable them directly, or indirectly, to get rid of a nuisance throughout the country, which was universally accepted and acknowledged, namely, the intermarriage of the domestic well with the domestic cesspool. His second reason was, that he believed a resolution going forth from that Congress of intellectual and scientific men collected from all parts of England—representative men —would strengthen the hands of all local authorities throughout the kingdom, and enable them to carry out the provisions of the law which already existed with reference to the pollution of water; and if they found by experience, as many had done, that those provisions were inadequate, would enable them to go to the Government and demand the reform which they believed to be necessary.

Mr. Adams (Maidstone) thought it would not be right to pass altogether unnoticed some remarks made by Dr. Thorne with regard to chemical analysis, which, if they had their full effect, would do damage to the cause of chemistry, and ignore the assistance which might often be obtained by that science. He was quite sure that Dr. Thorne would agree with him that, in many cases, chemical analysis was useful. A very small amount of the potent animal influence, disease, germ, or whatever it might be called, might exist in comparatively pure water which came from a public company, and might not be traceable by any means at the chemist's disposal. On the other hand, in country districts where almost every person had his private well in connection, or closely allied with the cesspits, the evidence which could be got by the chemist was very much more obvious and tangible. Perhaps he might have no means of detecting and isolating the germ of disease in sewage, but it was by its associates generally that they could, as chemists, track it out; in nine cases out of ten disease germs would have those associates, and by the discovery of those an alarm note might be struck, and hence chemistry would be valuable. Therefore, he ventured to enter a quiet protest against Dr. Thorne's remarks being taken to signify more than he would wish them to in throwing any doubt on the important results oftentimes obtained by chemical analysis.

Dr. Thorne said he entirely agreed with what had allen from Mr. Adams. His remarks applied solely to he Caterham water.

Mr. Birkett said he had not the good fortune to be a cientific man, but he was sure that very few had given greater consideration to this subject than he had. The pollution of water was the most fruitful source of disease. The contamination of dwellings from sewer-gas was lso a direct cause of disease, and he wished to draw ttention specially to the great evil which existed in large towns like Manchester and Liverpool, where the area of he household was so limited that it was absolutely impossible for the inhabitants to breathe pure air. When ach individual imbibed about two and a half hogsheads f impure air each day, it was easy to conceive what the ffect must be on the system. Therefore, whilst attacking the pollution of water and defective sanitary arrangements as going to the very root of the evil, he also hought there should be legislative enactments which hould prevent builders or land owners putting up houses with rooms of less than a certain size, and on a suffiiently large area to allow of thorough ventilation.

Mr. Colbrook said he had previously asked whether filtration would remove poisonous germs from sewage, and the reply was that it was doubtful. He wished, further, to know what would be the effect if the excreta of infected patients in towns were taken to a sewage farm and percolated through the land—would the germs be thereby destroyed? or would the effluent water convey germs to the river from which towns lower down would take their supply.

Mr. Ernest Hart said there was a vast amount of scientific evidence which would satisfy the mind of any layman; he believed that the theory that this poison did, and could, multiply itself almost indefinitely, was true. He referred more especially to the most recent researches of M. Pasteur on charbon and the splenic disease of cattle. The smallest quantity of blood taken from an animal dying of this disease would communicate the particulate poison, which there was great reason for comparing with the particulate poison of the typhoid disease. Pasteur showed that a single drop of blood of an animal affected with splenic disease might be inoculated in a culture-fluid, and produce an indefinite multiplication of that particular poison; that a drop taken from that culture-fluid passing on to another would produce similar matter in the second, and so it might go on almost indefinitely, and a single drop taken from any of these cultured fluids, and, therefore, indefinitely diluted, if it were a mere mechanical dilution, would prove intensely poisonous to the last series of animals, and would excite the same disease with absolute certainty. Similar evidence had been obtained as to the poison of septicæmia, or blood-poisoning. Therefore, there was evidence apart from absolute facts, that a particulate poison like that of typhoid, might, and did, out of the body indefinitely multiply itself. As to filtration, there was no doubt it had a very great influence, and especially filtration through the ground, and through ground filled with the rootlets of growing plants in destroying typhoid poison, but it could not be absolutely relied on. As Mr. Latham had pointed out, these germs fertilised and multiplied much more readily in darkness. Some attempts had been made to reduce almost to a matter of measurement the bulk of water, the amount of air, and the quantity of light necessary to destroy these germs, but it was perfectly well known that all flowing streams tended to purify themselves, that if you oxidise any of these ferments, which were organic ferments of low structure, you practically disintegrated them, and filtration through the earth into a river which then flowed exposed to light and oxygen were conditions which tended to destroy the poison. Still, you could not depend on them absolutely, because there might be fissures in the land, and instead of filtering, the poison might pass through the fissure, and be taken direct into the stream. Therefore, the rule should be universal, that wherever typhoid excreta were known to be such, they should be disinfected or burned before being buried, because one of the very last cases he had occasion to investigate of typhoid, was a case in which the excreta of one patient had been buried in accordance with what was believed to be sanitary rules, but having been buried in gravel, it found its way into a well some 30 yards below, and gave rise to an epidemic. The rule should be to take the precautions referred to in the resolutions, and, in addition to that, wherever typhoid excreta were known to exist, to have them destroyed.

The Chairman said if he did not think the resolution was of a practical rather than of a medical character, he should not be disposed to put it to the meeting. As far as he was concerned, he had no difficulty in accepting the views propounded by Dr. Thorne and Mr. Hart, but he might accept views and yet not feel entitled to record an opinion upon them; and on medical and scientific questions of this kind he preferred to take this position—to base himself on the inquiries and opinions of the highest authorities on the subject; but doing that he did not wish even then to carry the matter too far, but to limit the expression of his opinion a little further, and to say that he wanted some practical view which addressed itself to his own mind, and upon which he could feel himself entitled to exercise a judgment before pronouncing an opinion. In this case he was not prepared to pronounce an opinion on the scientific question raised by Mr. North; but, in the papers of Dr. Thorne and Mr. Hart, and in the experience and knowledge of the gentlemen present, there were ample reasons to entitle them to express this conclusion, that a comparatively minute quantity of the poison contained in the evacuations of patients of a certain kind, when subjected to conditions favourable to its development, might lead to the infection of large volumes of water. They had ample evidence to justify that proposition, and the practical conclusion to which the resolution led was one about which there could be no difference of opinion.

The resolution was then carried unanimously, and the Conference adjourned for luncheon.

On re-assembling,

Mr. Sillar said he should have liked to have addressed the meeting, more especially in connection with the town of Aylesbury, and the sewage work there, but it had been frequently described before, and it was not necessary to repeat it. He said that, some years ago, the great difficulty towns had to encounter, was that there were no known means of economically dealing with this great question, but now many ideas had been started and experimentally tried, and it was admitted that there were several good plans for getting rid of sewage, so that the difficulty rather lay in the choice. He was not going to say one word in favour of the Aylesbury process, as it was well known, and had been visited by thousands of people, and he had never heard anything but satisfaction expressed at what was seen. The objection which seemed to be generally started was as to the cost, and as to that he preferred to say nothing; because, whenever people were pecuniarily interested in any process, their words were received with great caution; therefore, he should prefer people making their own inquiries. He would rather speak on the general question of sewage precipitation and treatment. This question had been left to private enterprise. Whether it was right or wrong that this should be done was perhaps open to doubt; but so long as it was left to private enterprise, it must be done from some hope of reward. Patent rights were limited to a certain number of years, which soon passed away, and unless towns had some outside pressure put upon them to justify them in increasing expense, they much preferred the path of inaction. Delay was what they liked, and he could quite enter into the feelings of gentlemen who had charge of the expenditure of money for towns, for it was a most unpopular thing to engage in any expenditure necessitating the levying of rates, unless they were really compelled to do it. There seemed to be no compulsion exercised, because the excuse was so plausible: "we really do not know what to do." The Native Guano Company, which he represented, had done its part in the work, and he believed they had solved every practical difficulty. The works were open to the inspection of anybody, and there were gentlemen present who had seen them, and could testify that the effluent water was practically innocuous; that there was no offence whatever about the process; that the manure so made had a very high agricultural value; and that it could be done at a comparatively moderate cost. At present there was a great depression in agricultural industry, and one of the principal reasons why this was not more taken up was that the farmers had not money to spend in manures. In fact, the land was suffering from the poverty of agriculturists. The result of an experiment he had made with this sewage manure was that one seed of oats planted by himself with the manure produced in the autumn upwards of 7,[illegible] grains. This showed that the deposit, preserved from sewage without using those elements which destroyed the manure, had a very high agricultural value, and he believed that the value consisted in this, that it was the natural manure for the ground. On this principle, it had been recommended that it should be tried on the continent, where people suffered so much from disease of the vine, and he had the satisfaction of seeing in the *Times*, a few weeks ago, a statement that for the first time in history the ravages of the *phylloxera* had been suspended by the use of manure, the basis of which was manure produced at Aylesbury. He believed the agriculture of England would be benefited when a little more pressure was put on towns to do something, and when they were taught that however expensive it was to purify the sewage, it would be still more expensive not to do so.

Sir Henry Cole briefly stated the substance of his paper, "Progress with Sewage since the first Congress of the Society of Arts in 1876, submitted to the fourth Congress, in 1879." (See p. 123.)

Mr. Cresswell also stated the substance of his paper "The Thames and its Tributaries" (see p. 127), and concluded by proposing the following resolution:—

"That this Conference recommends the Council to arrange that a Deputation of Peers and Members of the House of Commons, with Members of the Society, may wait upon the First Lord of the Treasury, the Home Secretary, and President of the Local Government Board, in order to urge the necessity of purifying the Thames from sewage without further delay, especially in the metropolis; and to request the Government to bring in a Bill to charge the Thames Conservancy Board with doing the work, and obtaining the funds through the Metropolitan Board of Works, according to the precedent of the action of the School Board for Public Elementary Education."

Sir Henry Cole seconded the resolution. He thought the Metropolitan Board of Works was in this matter the greatest sinner. The sooner they could make use of the Thames Conservancy Board to do the work, and get rid of the pollution of the Thames, the better for the health of London.

The Chairman pointed out the difficulty which occurred to him in point of form. The proposal was to request the Government to bring in a Bill charging the Thames Conservancy Board with the duty of purifying the Thames from sewage without further delay, especially in and near the metropolis, but, as he read the resolution, including the whole of the Thames. It then went on to say that the Thames Conservancy Board were to obtain the funds from the Metropolitan Board of Works. Now, they could hardly be expected to pay for purifying the whole course of the River Thames.

Mr. Rawlinson, C.B., said it would be very difficult for him, as a Government official, to say much on the question. He had listened with great interest to the remarks which had been made, and he did not know that he had any objection to make to anything which had been said. The subject had been put forward in a very interesting and somewhat amusing form, but of course he could not tell tales out of school, or open up all the reasons why the Local Government Board did, or did not do, certain things. It must be self-evident, when the matter was calmly considered, that where there was a multiplicity of inventions for the purpose of dealing with sewage, the Local Government Board, if it took up any one of these schemes and advocated its application, would offend the promoters of all the others. But it was not true to say that the Government had not done anything. It had done a very great deal. It had established a Royal Commission, and he saw beside him Professor Way, who was his colleague on the Commission, and he would say, no doubt, if appealed to hat he worked most earnestly with his colleagues at hat question, how best to deal with sewage, for ight years. They examined all the processes known t that time, visited most of the places where sewage 'as attempted to be dealt with, and analyses were iade, not by ones or twos, but by hundreds; and ne member of the Commission, in the most liberal ianner, out of his own pocket expended not less than 2,000 to facilitate the experiments of that Commission. ince then there had been great progress, and the Acts ad been amended. Sir Henry Cole had stated that iere was one dictatorial crotchet for all sorts of cases, nd that was that the inspectors of the Board drove very district to purchase land. He did not know how far iat was so, but they (the inspectors) certainly had no uthority from the Board to do so. One thing he 'as bound to say, that as far as they were informed by hemists, precipitation of any kind did not give an ffluent that could be called pure. Assuming it precipitated some of the salts of sewage, the effluent took way certain of the salts of the precipitants which were ut in, and, therefore, there was practically an impure rater; either it might be injurious or not, he was not repared to say, but he would state this, that there rere various chemical and precipitating processes rhich had been in operation now for several years, gainst which, as far as his knowledge went, there had een no complaint, either from resident owners or ripaian proprietors, as to the character of the effluent. 'hat should be taken into serious consideration, and it night be a question as to whether, although an effluent ras not chemically pure, the patentees or towns who hose to treat the sewage in that way should not e permitted to do so; for, in the eyes of the law, hey were, and must remain, responsible for any ollution that might occur below them. He thought t would be most monstrous if the Government made a iard and fast rule, and declared that in all cases land nd broad irrigation alone should be used. With regard o the towns below the intake of the water on the 'hames, he expressed the opinion that, if towns elow the intake of the metropolitan water comanies would precipitate according to the best rocesses, he did not conceive that the Thames vould be injured by the clarified water going in. f the Metropolitan Board were, as most unquestion-bly they were, under the obligation to precipitate and o clarify the whole volume of sewage now taken in its rude state into the Thames, they would be doing no more han the duty that Parliament imposed upon them and thers. And even though it would cost £100,000 or 200,000 per annum, that should not stand in the way of ts being done. They had arrived at this point, that, with egard to the dealing with sewage, it was absolutely mpossible for scores of towns to acquire the land iecessary to purify it by broad irrigation. Again, ll through Lancashire, Yorkshire, and other manufacuring districts generally, it would simply destroy the rade to compel them to take their polluted water away nd filter it through land at a distance. The water hey must have dirty or clean; as the life of their rade depended upon it; it was that which produced he income, and it must be treated on the spot. 'here had been a great bugbear raised with regard to he pollution of rivers, as if that was the greatest possible crime, and a thing not to be tolerated under any ircumstances. He could only say that there were two ides to that question. Taking the West Riding of 'orkshire, where the woollen and worsted trades were iow situated, the value of that trade in the year, Proessor Way and himself reported, might be shown by he fact that the gross sum expended per annum in those rades amounted to £75,000,000 sterling. Comparing hat with the rent of land, it sank into insignificance. ssuming that there was some injury done in polluting hese streams by that trade, and that they never could iope to get them back into a pure state, he still made the assertion broadly that, bad as the rivers were polluted, when a detailed examination was made by the medical officer of the district, if the waters of those rivers were not used for domestic and drinking purposes, they were very little injurious to the health of human beings. A polluted river was not necessarily a health-destroying river. There were probably no rivers so polluted as those which traversed Manchester, but they had a house-to-house detailed examination, and returns of the local mortalities, and though he did not mean to say that these polluted rivers did not effect some injury, singularly enough, the mortality on the margin of those rivers was much less than in streets further away, where there were a superior class of houses, but where there were cesspits more crowded together, and there was less space for ventilation. He did not mean to say that these rivers should be left as they were, but the greatest obstruction and pollution from manufacturing was not so much the chemical ingredients as the mechanical refuse thrown into the bed of the stream. Many of the fluids passing from a manufactory, apparently deleterious, were really purifiers, and it would be a bad day for Lancashire, Yorkshire, and other places where manufactures were carried on, if the fluids from dying and bleaching works were prevented going into the stream until something was done to keep excreta entirely out.

Captain Douglas Galton said he should like to supplement somewhat the history of the pollution of the Thames, so ably described by Mr. Cresswell. The Metropolitan Board of Works was created in 1855 for the purpose of purifying the Thames, and sewering London. That duty was laid down in the Act constituting the Board. They were told to draw up a scheme for relieving London of its sewage, and for placing its outfall beyond the limits of the metropolitan district, the plan to be subject to the approval of the Government. Mr. Frank Foster drew up a plan, and, when he died, Sir Joseph Bazalgette succeeded him. The plan was submitted to Sir Benjamin Hall, the First Commissioner of Works, who appointed three gentlemen to report upon the scheme, Mr. Simpson, President of the Institute of Civil Engineers, Mr. Blackwell, C.E., and himself, of whom he was the only survivor. They examined most carefully into the plan, and suggested some alterations in the capacity and the details of the sewers, the object of which was to prevent the flooding of low-lying districts, which they anticipated, and reported that the outfalls at Barking and Crossness were certain to cause deposits of mud in the channel, and to prove injurious to the sanitary condition of the river. After long inquiry, they recommended that the sewage should be carried to a point in the river about four miles below Gravesend, and there turned into the river, where it was above a mile wide, in very deep water, and where the inflowing tide comes in upon the south side and the outflowing tide goes out on the north side, and they suggested that the outfall of the sewage should be placed at that point. They further suggested that by means of a channel, constructed on the principle of utilising the rise and fall of the tide, the sewage from 91 square miles of the metropolitan area, out of 118 square miles, the total area, might be carried to Sea Reach by gravitation, without any pumping, leaving the sewage of 27 square miles only to be pumped, whereas the scheme of the Board required the sewage from 93 square miles of the metropolitan area to be pumped, some of it twice over, and removed the sewage from 25 miles only to Barking by gravitation. They showed that the capitalised cost of the pumping under their scheme, and of the sewer required, would be less by several millions than the capitalised cost of the pumping done by the Metropolitan Board of Works and of their sewers. This report was referred to the Metropolitan Board by Sir Benjamin Hall, and discussions were taking place upon it, when the then Government went out. A new Government came in—Lord John

Manners succeeded Sir Benjamin Hall—he probably did not like the responsibility of the decision, and, therefore, introduced an Act of Parliament which relieved the Government from the necessity of approving of the plans of the Metropolitan Board, and they were left to do as they liked. We now saw the result. It would be quite possible to carry the sewage down to Sea Reach, but we could not now, without an enormous reconstruction of the sewers in London, carry down there by gravitation the quantity which might have been carried had the scheme of the referees been adopted in the first instance. He believed, however, that it would still be a more economical plan to carry the sewage to Sea Reach than to spend £100,000 or £200,000 a year in clarifying it. The referees further suggested that, where there were outlying districts around London not included in the Metropolitan Board of Works districts, there should be some arrangement by which the sewage of those places should be brought to the outfall at Sea Reach into connection with that of the metropolis, because the referees saw the very great difficulty which must arise, in towns like Richmond above London, and again in towns beyond the metropolitan boundary below London, if they were to be obliged to devise independent schemes of sewage. The only point in which he differed from the resolution was with regard to relieving the Metropolitan Board of Works from the duty. Because, notwithstanding they had not fully performed the duty of placing the sewage where it would not pollute the river in the metropolis, still they had done an enormous deal in London; their works had been carried out remarkably well; their embankment was very good, and the sewers were admirably constructed; and he was quite certain that Sir Joseph Bazalgette would be competent and prepared to carry out any scheme he was ordered to do by the Metropolitan Board. He, therefore, thought the duty should rest entirely upon them to complete the fulfilling of the conditions of their original Act of Parliament.

The Chairman said he still had some objections to the form of the resolution. Although one objection he made had been remedied, two other objections still occurred to him. He thought the resolution was too vague in its statement of the evil to be remedied. The proposal was to purify the Thames without delay, but if they passed a resolution of this kind, meant to be directed against the non-fulfilment of their duties by the Metropolitan Board of Works, it ought to specify the respect in which they had failed. Then the conclusion was that they should ask the Government to charge the Thames Conservancy Board with the doing of this work, taking it out of the power of the Metropolitan Board, but making that Board raise the money for the operations of another body. Now, whatever they might think of the shortcomings of the Metropolitan Board, it did strike him as very useless to go to the Government and ask it to transfer the power from the properly-constructed authority in the metropolitan area, and to give their business to another Board, and still make them pay for it. He, therefore, thought the resolution wanted a further modification, and if they thought it necessary to draw public attention to the failure in their duties of the Metropolitan Board, that failure should be specified, and the Board itself should be called upon to remedy the failure.

Mr. Chadwick, C.B., perfectly agreed with the tenour of the Chairman's objection. Whatever resolution was passed should, he thought, be subject to consideration and discussion in the Council, for there were a great many objections to each of the points which might be heard in the Council, but which would be too long to discuss there. He could occupy an hour or so upon one or two of them. The great point was to have the charge that the Metropolitan Board had failed in its duty fairly determined. That at present, was somewhat *sub judice* between them and the Thames Conservators, who alleged that they had failed, and that what they ought to do was to prosecute that settlement. It was quite clear that they had utterly failed, for they had expended some four and a-half millions of money to purify the Thames, and had utterly failed to do so, although by other methods, of which they had now practical examples in different parts of the country, half the sum of money spent would have accomplished the object. Instead of sending the whole mass of sewage over 11 miles down the river to one point, the antecedent plan which he had proposed was, by sewers and pumping power, to radiate it out in the direction of demand, or as facilities might occur for disposing of it. A German engineer who had charge of a river in similar conditions to those of the Thames, and who came over here to inspect the metropolitan plan, rejected that plan, and went back to the system of radiating out the sewage in the direction of demand. That was now in progress in Berlin under impartial, and, he hoped, competent skilful treatment. He doubted if the Metropolitan Board was large enough to carry out this enormous task, and thought it would have to be reconstituted. On this ground, he saw considerable difficulties in the way of the resolution as it stood, and thought it would be better if it were simply confined to a statement of the fact that, according to all accounts, the Metropolitan Board of Works had failed in effecting its object, notwithstanding the enormous expenditure, and that that failure ought to be the subject of inquiry by a select committee in Parliament or otherwise.

Mr. Cresswell said that havimg received such an intimation from the Chairman, he would most willingly yield to the invitation given, but he felt he had no right to do so without the consent of the meeting.

Mr. James Wylde remarked that he could fully confirm, from personal observation, the truth of Mr. Cresswell's statements in respect to the Thames. Last year he had made, on frequent occasions, between April and August, careful examination of the river from Richmond to Gravesend, and had never seen it, during the last 20 years, in a worse condition than during July and August of 1878. The soluble and suspended matters were very great, and at a temperature of 80° to 84° Fahr, the stench, in the months last named, was sickening. Mr. Wylde added that he had accompanied the Metropolitan Board during their trips to Gravesend in November. The results were negative, but this was easily accounted for. Heavy floods had preceded the date of these trips, and they were undertaken when the air-temperature, on each day, did not exceed from 32° to 38° Fahr. Under such circumstances, of course, it was scarcely possible that the river could be offensive, as the filthiest ditch would then cease to be so.

Mr. Birkett said he should heartily support the resolution if it were so enlarged as to include all Conservancy Boards, because it was not only the Thames Conservancy Board, but Boards throughout the kingdom, which had similar work to perform. He thought it would be also well to leave it a question as to who was to pay the expense. The tendency of the discussion seemed rather to be in the direction of legislation in these matters which he thought was a mistake. The duty of the Society was to find out the evil, and then the suggestion would go with such weight to the Legislature or Government, that it would be received with some consideration.

The Chairman said the proposer and seconder of the resolution now proposed to change the form to the following:—"That this Conference recommends the Council to arrange that a deputation wait upon the Government to urge the necessity of taking further legislative means to prevent a continuance of the pollution of the Thames by sewage." If no one else had any remarks to make he would put it to the meeting.

The resolution was carried unanimously.

Mr. Chadwick then stated the substance of his paper, Course of Inquiry as to Works of Sanitation, and s to their expense and results." (See p. 130.) He also ggested that in all places where the death-rate had not een decreased, special investigation should be made to scertain why it had not done so. He maintained that or every £1 per house wisely expended on sanitary orks, the death-rate ought to be reduced by one per 1,000.

Mr. Chadwick further stated, in respect to the ourse of examination displayed in the paper on the orks at Croydon and Bedford, and undertaken for the formation of the Belgian Government, that such examinations ought to be made general as to the results of ll outlays for sanitary works, and should be employed ore closely, strictly, officially, and responsibly for the rotection of the ratepayers against works which, nstead of relieving, aggravate the burthens and the evils hich are inherent to insanitary conditions, and throw iscredit upon sanitary science. The first questions which ught to be insisted upon, in relation to past expenditure n works for sanitary purposes were—Did they or did hey not reduce death-rates as promised? and—Were hey paying? If not, there had been culpable ignorance, alfeasance, or misfeasance, to which serious reponsibility ought to attach. For the future such xaminations would serve to show more clearly han was yet generally known what did do, as ell as what did not do. On such examinaions, as those he had displayed in his paper, it as proved that an expenditure of about £5 per house, r of about £1 per head of the population, for combined orks of water supply, and house and main drainage —roughly carried out, as they had mostly been— ffected reductions of death-rates to the extent of five er thousand of the population. In other words, every ound per house of expenditure correctly applied had ffected and would effect a reduction of one death per housand of the population. An examination of the esults of some millions of expenditure, attended with ugmented burthens on the rates, was due to the rateayers and to future progress. Long after the works on hich that expenditure was incurred had been comleted, and were in full operation, the death-rates in the etropolis, which an effective expenditure under sound anitary science would have largely diminished, had emained stationary or had increased. For the two last ompleted decades, the general death-rates in the metroolis had increased. It was proper to note, too, on the ewage question, as showing how much light was et needed—that even Sir Henry Cole had much to earn, and had especially to inform himself more orrectly as to the character and value of the preensions of some of his authorities. In his paper n the sewage question he had used these terms:—'An opinion has been expressed by civil engineers of nowledge and experience that sanitary science has een retarded by the antiquated prejudices of the inpectors of the Local Government Board in favour f irrigation. A late president of the Institute f Civil Engineers once said to me—'The simple esult of the utilisation of sewage by irrigation s the production of a penny cabbage at the cost f 6d., and a pestilential neighbourhood besides.'" It is such engineering as this that allows a double and hree-fold waste of water in dry weather, and, in wet weather, throws the rainfall and the storm water, which is due to the river, into gigantic tunnel sewers —by all of which excessive and wasteful dilution the uantity of manure had been reduced to a pennyworth r even a halfpennyworth in a ton of water, and rendered almost valueless for carriage. Some such augmentation in expense as had been spoken of, with incommensurate amount of production, might be displayed as attendant on the works of insanitary ngineers. But the value of their dicta was displayed from more correct and economical sanitary works inside and outside the towns—inside the towns in self-cleansing house drains and smelless sewers; outside the towns in unprecedented crops, such as of more than a hundred tons of mangolds to the acre, and in surprising cabbages of half a hundredweight each, of superior quality, and several worth sixpence each; and, generally, in repeated instances such as were displayed at Croydon and Bedford, where, whilst the common agricultural production was as one, and market gardening as three and a half, the sewage yield was as five and more, and the qualities superior. As to the economical results, an official inquiry on sewage farming had declared it to be remunerative for the investment of capital under fair conditions of appropriate economy, unextortionate rents, and appropriate skilled labour. It might be averred generally that the efficiency and value of sanitary works such as those in question, and of the qualifications for sanitary engineering, might be tested popularly by the nose, from foul smells in the house, in the streets, and on the field, which denoted waste of manure, as well as by continued excessive death-rates and ill-remunerative works.

Mr Baldwin Latham then stated the substance of his paper, "Works of Sewage and Sewage Disposal—Croydon Sanitary Authority." (See p. 136.)

Sir Henry Cole asked how long the brick rubbish used for the filter would last?

Mr. Latham said there was no limit practically, because it was self-purifying. It was worked on the intermittent principle. Oxidation took place, and the soluble matters were washed away. A filter, six feet deep and one acre in extent, would purify the sewage of 3,000 people.

Sir Henry Cole said he was not, as some people seemed to suppose, a disbeliever in irrigation. He suspended his judgment upon the value of water-carried raw sewage for irrigation, but in order to show that he was quite unprejudiced, he would tell the story of a sewage farm whose results were about as good as Mr. Latham's. The Duke of Sutherland's seat at Trentham was within two miles of Longton. That town had a very few water-closets, but a great number of houses, of which the middens drained into the sewers, whilst all the storm-water was kept out of the sewers, and, therefore, all the valuable properties of the excreta from the middens were preserved. The Duke had, also, an inexhaustible quantity of thirsty land at Trentham, and the result of taking the sewage of Longton, and putting it on his farms as it was wanted, had the effect of doubling the annual value of the land, whilst the town of Longton gave him £500 a year to do it, and rid the town of its filth. But this financial success was nearly unique.

Mr. Grindle (of Hertford) said, being the engineer to the Buckhurst-hill Sewage Works, he might state that there were four filters, 40 feet square and 6 feet deep, made of crushed burnt ballast. This material, when examined under the microscope, appeared almost like a piece of charcoal, full of pores. These intermittent filtration works were constructed in 1872, and had been in successful operation ever since, and never changed. Each filter was allowed to rest 18 hours out of the 24 for aeration. The effluent had been analysed, and gave very satisfactory results. It was poured into a river called the Roden, which was a very small stream. He should think the effluent was about one-tenth of the stream.

Sir Henry Cole said one of the highest chemical authorities having analysed the water in a similar case, thought it was quite safe to put the effluent, filtered in that way, into a stream of 10 times its volume, but another authority, equally eminent, said the stream should be 50 times the volume.

Lieutenant-Colonel Jones next gave the substance of his paper, "Sewage Disposal at Wrexham." (See p. 141.)

Mr. Lemon asked Colonel Jones if he could give a description of the machinery he used for drying sludge?

Colonel Jones said he described at the last Conference the machine which he was then using. He was at present using another on the same principle, which consisted simply of an iron cylinder of about 4 feet in diameter, made of light boiler plating, about 29 feet long. The sludge was poured in at one end, and there was a worm inside which kept it stirred about, and an iron pipe with a fan drew the gases from the furnace through it, the sludge being stirred about in the presence of the gas. The only essential principle consisted in the action of the sulphurous acid gas of the fire on the sludge, forming sulphites of ammonia instead of allowing the ammonia to escape into the atmosphere. The same principle was utilised in the other mode, which was simply passing the sludge through the furnace itself, but he thought that drying was facilitated by blowing the hot gas through it instead of allowing it to pass through the heated chamber.

Mr. Colebrook said he was chairman of the Reading Sewage Farm Committee, and he might give the result of their experience last year, particularly in the growth of mangold under irrigation. The highest weight per acre was 110 tons, and the lowest 77 tons, which, he believed, was the heaviest weight ever known to have been grown. There was this peculiarity in the growth of this mangold. It was intended, in the spring of the year, to irrigate the land while the crop was growing, but the spring was wet, and they were not able to hoe the land when they wanted, and when they were able to do so the weeds filled the trenches, and they could not get the sewage on to the land while the crop was growing. He pointed to that for this reason, that he believed it was quite possible to overdose the land with sewage, and the result they obtained was chiefly owing to not having done so. The crop of rye grass was equally good. Last year they cut six excellent crops of not less than 20 tons per acre each crop, whilst the year before they had seven crops. This year, the spring being so backward, they had lost the first crop entirely. They had rigidly excluded storm-water, and he attributed a great deal of their success to the fact.

Mr. Chadwick asked how they got on with cabbages?

Mr. Colebrook said they had only tried cabbages twice, because the farm was as yet imperfect. One crop was very good, but the other was spoiled by being overdosed with sewage, because they had not a sufficient area of land ready to take it, and were obliged to sacrifice the crop for the sake of disposing of the sewage?

Mr. Cresswell asked Colonel Jones if he had had sufficient experience of Mr. Shone's machine to say whether, in such a place as Southport, where it was absolutely necessary to have a series of pumping engines, such a machine might be applied with advantage; and, if so, whether his experience enabled him to tell the Conference whether there would be any economy in it compared with the ordinary steam-engines?

Dr. Seaton asked Colonel Jones whether he apprehended that some extra means would have to be provided for flushing the sewers if storm-water was excluded?

Colonel Jones said his belief was that, if the sewers were constructed for carrying sewage alone they would never require flushing; the ordinary flow of the sewage would be sufficient, being always moving; but if, from any exceptional cause, they require flushing, it could be done very readily, either by letting water into them or from damming it up temporarily in some places and then letting the water go with a rush. He thought it a great mistake to depend on the rainfall for flushing. It came at exactly the time you did not want it. It never came in dry hot weather, when the sewers were full of sewer gas; and when it did come it left behind it a lot of road detritus which choked up the sewer. In reply to Mr. Cresswell's question, he could not say that he had had sufficient experience to form a very decided opinion as to the system answering on a large scale, but from all he had seen he saw nothing to prevent it, and it was thoroughly worth a trial. He knew that one place had almost completed arrangements for trying it under somewhat similar conditions to those named, so that it would not be long before the question could be answered from actual experience. The first objection which occurred to every one was, that compressed air was an expensive power but when it was examined it would be found that compressed air had been always adopted with additional friction, which did not enter into Mr. Shone's application of it. He regarded it here simply as a transmitter of power just as a column of water would do, or a strap from one pulley to another. He then explained, by the aid of a large diagram, the action of Mr. Shone's ejector.

Captain Galton said it acted very much like a ram.

Colonel Jones said there were often difficulties in dealing with pure water and sewage in the same place, but it would be very simple to have two of those ejectors, one to supply the house with clean water, and the other to eject the sewage, both worked by one little air compressor. The great advantages of this arrangement was that the ejectors might be laid down in different parts of the town, and all worked from one central point, and water power might be applied for compressing the air just as well as a steam-engine.

Mr Henry Masters then explained the principle of sewer ventilation, "The Double Check System of House Drainage." (See p. 144.)

Mr. Alcock asked if he rightly understood the system to be that of carrying drains under every house with a pipe on each side.

Mr. Masters said the principle consisted of carrying the air right through a pipe which was open at both ends, so as to keep the drain constantly free from gas.

Mr. Banner then demonstrated his principle of system of house sanitation, and exhibited a model of his cowl. (See p. 147.)

Dr. Yeld asked if it was not found in some experiments made at Kew, that open tubes were equally as effectual as cowls?

Mr. Banner said that was the opinion arrived at under the conditions in which some were tried. The Banner cowl was not one of them. He then fitted a small cowl to the end of an india-rubber tube 60 feet long to show its effect in extinguishing a light at the other end. He said with regard to the experiments at Kew, there were several practical ways in which the question could be properly tested without going to such experiments as were adopted there. At Guy's Hospital, for instance, the discharges from one section of the hospital were delivered into a 15-in. drain, 300 or 400 feet long; a cowl was raised upon that, and the power of it was to draw the air or gas the reverse way from that the sewage was running, and discharge it above the roof, and since that had been done they never had the smallest smell at the inlet. If it were contended that it could be done without, all they had to do was to have the cowl taken off. There were hundreds of places where the same thing could be done.

Mr. Wolstencroft suggested that the small model cowl which Mr. Banner had been exhibiting was not quite the same as those practically used, because there was no arrangement to enable it to revolve, and that it acted more closely on to the tube.

Mr. Banner explained that this made no appreciable difference.

The Chairman said he thought the Conference could not go into the merits of specific inventions.

Dr. Seaton (Nottingham) next read his paper, "On the Substitution of the Pail System for the Privy Midden System in Nottingham, and its effects in reducing the Mortality and Sickness from Enteric and Continued Fevers." (See p. 155.)

Mr. Birkett asked if Dr. Seaton had made any calculation as to what was the saving to be derived per thousand of population where the sewage was properly utilised?

Dr. Seaton said they did not manufacture it all.

Dr. Tripe said it would be interesting to know what was the reduction in the death-rate, in consequence of the introduction of this system.

Dr. North asked what was the cost per house, this being a point on which many towns wanted accurate information, and it was hardly possible to get to know the precise cost of this plan, because it was generally so mixed up with other expenses. No one doubted it was an enormous advance on the old midden system, and the great question for local authorities to consider was what was the cost.

Dr. Vacher asked if the sewage in pails was at once treated with dry sifted ashes, because there would be a great difference whether the soil was left in pails, as at Rochdale, or treated with some dry material at once. In the case of typhoid or cholera patients, it was very important that something dry should be thrown over the excreta, so as to keep them down in the pail, and prevent them polluting the air.

Dr. Yeld asked what increase in the rating had been caused by the introduction of this system. It was a very important paper, but it was too late for a public discussion upon it. Many large towns were experimenting in the same way, and the tub or pail system would be more readily adopted were it not for fear of the expense, inasmuch as local Boards were very often more apt to consider the question of cost rather than that of the public health.

Dr. Seaton said of course the value of the manure was considerably increased by collecting it in pails. At present the value was 2s. 6d. per ton as against 1s., under the old privy system. He could not furnish the cost per house, but he could give the total cost of the working of the night soil department for the past year. In answer to another question, he said the owner of the houses bore the cost of the alteration.

Mr. Alcock asked if they found the owners objected to make the alterations, and if so, whether they had had any experience of their power to enforce the new system?

Dr. Seaton said in some cases they had had a good deal of opposition, but in those cases they had proceeded against the owners for a nuisance, and had found no difficulty in getting the law enforced. He had had no hesitation in declaring that a privy midden in close proximity to houses was a nuisance and injurious to health.

Mr. Alcock asked if he had had any experience with regard to isolating cases of infectious disease by the working of the new system?

Dr. Seaton said it was one of the advantages of the pail system that, when infectious diseases prevailed in a house, you could take special means for the disinfection of discharges. They used dry ashes as much as possible. The pails were simply small movable middens, into which the dry ashes and refuse were also put.

Mr. Alcock asked what was the frequency of removal, say, in an ordinary house, occupied by one person with a family or servants, or a tenemented house?

Dr. Seaton said there were altogether in operation at the present time in the extended borough 10,000 pails, and there were 15,000 removals per week, showing that some were removed once a week and some twice. The cost per pail was three farthings, the men being paid by the number of pails they brought in.

Dr. Syson asked if they abolished ash-pits?

Dr. Seaton said yes; the pails replaced the ash-pits.

Mr. Alcock inquired what the three farthings per pail covered?

Dr. Seaton said simply the labour of removal.

Mr. North said it was stated last year that at Rochdale the nett cost was £10,000 per year, or about £1 per house, which was a very considerable item to have to bring before a Corporation.

Dr. Seaton said the total cost of the night soil department during the past year was about £10,000, which included the removal of ashes.

Dr. Tripe said he presumed about £3,000 of that would be due to the removal of the ashes.

Mr. Longdin, Borough Surveyor of Warrington, said in that town there were about 4,000 houses on the pail system. They collected the excreta and ashes in separate pails, and took them to a depôt about one mile from the centre of the town, the ashes were simply burnt and screened, and the fine ash was mixed with the excreta and sold as manure, but they were not at all satisfied with the process; at the same time they held back, wisely he thought, for the present to see what other people were doing. The cost per head of the total working of the night soil department was, including interest on land and building, &c., at depôt, 8d. per annum.

Mr. S. W. North remarked that some of them were interested in towns where there was no collection whatever at present made by the Corporation, and they would like to know the cost of starting such a system. In the town he represented, to talk of an expenditure of £10,000 a year would frighten people at once. He believed it was said last year that the cost at Rochdale was £1 per house after deducting what they obtained by the sale of the manufactured manure.

Dr. Syson believed that the total cost at Rochdale, under the new system, was less than under the old. Certainly, at Manchester, the cost of the old midden system was very much greater than the cost of employing the pails.

Mr. Hewson said he resided at Rochdale, and he understood that the cost of the pail system was much greater than that of the old ashpit system; he also understood that in Manchester the cost of the night soil department had doubled within the last few years.

Dr. Yeld said there was a great increase in the cost at Birmingham owing to the adoption of this system.

Dr. Wilson said until the introduction of the pail system in Rochdale they could get no one to scavenger the closets at all, unless at a greatly increased cost. The charge when they gave it out by contract was yearly increasing, and there was a corresponding decrease of efficiency in the way it was done. At that time Rochdale was in the unfortunate position of having a death-rate very much in excess of what it ought to be, and if they considered the position of such towns, the question of cost ought not to occupy such a prominent position as it had done. In Nottingham they were under peculiarly favourable conditions, because they could at once get rid of the collected matter. It was made a strong point yesterday that there ought to be no appropriating of water from one district to which it more naturally belonged, and sending it to another, and Rochdale, on the same principle, thought it far better not to send their excreta, or poisoned water, into other districts. That was another and very serious element in the cost of this system. He could confirm what Dr. Seaton had said as to the lessened death-rate from fever, although he had not the statistics for the years since 1874, still the constant tendency of that rate was downwards. When Dr. Lyon Playfair inquired into the health of the town, it was found that Rochdale might be divided into two districts, one in a good sanitary condition, and the other in a bad; and it was then shown that the death-rate of that which was in a good sanitary condition, was 23 per 1,000. Since that time the town had largely increased, with a corresponding increase in the density of the population, but he could state now that the general death-rate for the whole was about the average which was then stated to be that of the district in a good sanitary condition, and to make up that rate, of course there were many parts where it was considerably under 20 per 1,000.

Mr. North said no one could doubt that the pail system was preventive of disease, but the question was how much it would cost a Corporation to do that which it ought to do, in a case where hitherto it had done nothing? Judging from the knowledge he obtained at Rochdale, he came to the conclusion that the cost would be about £1 per house. At present, as far as he could ascertain, it cost the occupiers of houses on an average from 3s. to 4s. per house for removal at intervals of three or six months, when it was done by private enterprise, and not by the Corporation. This was about the cost in York.

Dr. Wilson thought that Mr. North had not taken into account the peculiar difficulty of Rochdale; the whole thing was forced upon it because it could not get rid of its manure, as many neighbouring towns could, having a large agricultural district surrounding them; but the total cost was much under £1 per house, probably nearer one-half that amount.

Mr. Schofield, of Rochdale, said that place had been passing through a period of transition from hand labour to machine labour, and although the cost of the machines had been considerable, that could not be taken as a criterion of what the system would do when it was got into fair operation, and it did not follow because the town had been put to a large expense during the past year, that it would be in the same ratio afterwards. When they commenced in 1870, they had only 527 closets under the pail system; it had gone on, until last year there were 950 without pails. Now there were only 1,000 of the population with the old closets, and 2,000 with water-closets, and probably within the next few months it would be entirely done under the new system, and that almost entirely without compulsion.

The Chairman said he hoped now he might be allowed to bring the proceedings to a close. The first question which occurred was how the previous Conference compared with the present, and would the result of the present afford a sufficient inducement to gentlemen to re-assemble next year. In that respect he thought he might congratulate the meeting. They had enlarged the subject matters of inquiry, and if some portion of the vast and complex subject had rather been put in the shade, it was simply from want of time to fully discuss every point. He referred especially to the subject in the paper of Dr. Seaton. This Conference had shown such a special interest in this subject that he regretted it was not taken earlier, but probably the Council of this Society were led to place it rather late in order of subjects because it had been discussed upon many previous occasions, and the Conference had already passed resolutions on the subject to which he would draw attention. In 1876 and 1877 the following resolutions were passed:—

1876.

That the protection of public health from typhoid and other diseases, demand that an amending Act of Parliament be passed, as soon as possible, to secure all house drains connected with sewers in the metropolis, and towns having an urban authority, should be placed under the inspection and control of local sanitary authorities, who shall be bound to see to the effective construction and due maintenance of all such house drains, pipes, and connections. Provisions having this object in view already exist in the Act constituting the Commissioners of Sewers in the City of London, in the Metropolis Local Management Act, 1855, and in the Public Health Act, 1875, but practically they seem scarcely sufficient for the purpose.

1877.

1. That the pail system, under proper regulations for early and frequent removal, is greatly superior to all privies, cesspools, ash-pits, and middens, and possesses many manifold advantages in regard to health and cleanliness, whilst its results in economy and utilisation often compare favourably with those of water-carried sewage.
2. That hitherto no mode of utilising the excreta has been brought into operation which repays the cost of collection.
3. That the almost universal practice of mixing ashes with the pail products, though it applies these as a convenient absorbent, and possibly to some extent as a deoderant, is injurious to the value of the excreta as manure.
4. That, for use within the house, no system has been found in practice to take the place of the water-closet.
5. That, although there are appliances and arrangements by means of which the sewer-gases may be effectually prevented from entering houses, they still do so in the great majority of dwellings, both in town and country, including the metropolis.
6. That it is of the highest importance, in a sanitary point of view, that the metropolitan and local authorities should exercise great vigilance with respect to this matter, and that it should be made by law the duty of these bodies to enforce efficient measures for the exclusion of sewer-gases from dwellings, and to watch over their being efficiently carried out under such a system of payment as shall not press too heavily on those at whose charge the work is done.
7. That in every large town plans of its drainage should be deposited with the local authorities, and be accessible to the public.
8. That all middens, privies, and cesspools in towns should be abolished by law, due regard in point of time being had to the condition of each locality.

He took it, therefore, that this Conference, not only this year but in previous years, had always been of opinion that privies and middens ought to be abolished within a reasonable time, and that the pail system was a vast improvement on those old methods of dealing with excreta. They had not exhausted, and probably had not had sufficient experience to exhaust, the question of the comparative cost of the pail system, which was a very interesting subject of inquiry from the point of view of those especially who believed in the system as one calculated to prevent the spread of disease, and who desired to know the cost of its application to the towns in which they were interested. They had had figures from time to time on the subject, and he would venture to suggest that, next year, their friends at Rochdale, who had been improving and completing their machinery, should come prepared with a special statement of the cost as compared with other methods of dealing with sewage, with the object, not merely of showing what they had done, but of informing the representatives of other towns on the subject, and of enabling them to judge how far the pail system could be applied to other communities, and at what comparative cost. He had always felt, and had said on former occasions, that at any rate the pail system was efficacious. You dealt with the evil at its source, and in some respects before its source—at any rate before the source of that great evil of modern times, sewer gas. If you dealt with excreta in the house itself, however troublesome and expensive it might be, compared with some other system, you dealt effectively with it from a sanitary point of view. There was also another advantage. It might be a costly system if you took the cost per head of the population, but, at any rate, you had this advantage, you were not sinking money which might be mistakenly sunk in large works, which might turn out to be constructed on some wrong principle, or which, even if they freed you from the source of evil, might carry it to your neighbours. Therefore, he said, that in the present state of knowledge as to the methods of purifying sewage conveyed by water, unless you had a large and dense population and some easy opportunity of an outfall, it might very well be the least costly method, in the long run, to be contented for the present with the pail system.

Iowever, he did not think it was a subject on which the 'onference would like to arrive at a resolution at preent, but he hoped their friends at Rochdale would bring urther details as to cost next year. During these two ays there had been a great variety of interesting papers nd discussions, and certain resolutions had also been assed. The first day was appropriated to discussion of he great question of National Water Supply, on which resolution was passed, and it was determined, after onsiderable discussion, that the meeting would adhere o the policy taken up by the Council and the Conerence last year, and throw on the Government of the day he onus and responsibility of dealing with the question y a Royal Commission of Inquiry. He did not know that the probabilities of action were by the Governent; if they acceded to the request of the Council, onveyed by the Prince of Wales, then they had reason o believe that the whole subject would be investigated y the most competent scientific knowledge, and cerainly no scientific men connected with this subject rould be otherwise than satisfied by the subject being ealt with, explored, and explained by such a machinery s that. If the Government did not accede to the reuest, then he thought that the Society of Arts should ake some action, without waiting for next year's Conerence, and he hoped they would allow him, as Chairman, n such a case, to press on the Society the necessity of aking some immediate action on the subject. Then ame the exceedingly interesting papers of Dr. Thorne nd Mr. Ernest Hart, and the contribution to the same ubject in the speech of Mr. Baldwin Latham. Dr. Thorne's paper was very interesting to him in more ways than one. It was interesting to all, because of ts ability, lucidity, and the remarkable characteristics f the case. It was precisely a case—simply explained s he explained it—calculated to convey to the public nind the ways by which scientific men could trace the vil to its source, and the use to society of the applicaion of such methods of scientific investigation. But it vas interesting to him from another point of view. As an ex-president of the Local Government Board, e was delighted that the medical department of that Board had an opportunity before that Conference of resenting itself in an aspect so favourable to all who were interested in sanitation. It was fulfilling preisely the true functions of the medical department of hat Board to undertake to conduct such inquiries, as hat department was a scientific one, and its duty was o conduct investigations which other persons might ot be equally able to conduct, which served to guide Local Government Boards throughout the country, and hese results were published in the annual reports of he Local Government Board, and thus were generally ccessible. On that matter a resolution was passed, of which the meeting would have no cause to repent. The emptations had been avoided of pronouncing as a mixed ody on a purely scientific question; they had eliminaed all that was purely scientific out of the proposal vith which Dr. Thorne's paper concluded, and passed a esolution which he thought they were justified as ractical men on the evidence before them in arriving t. Then he came to the paper of Sir Henry Cole, who first referred to a suggestion of his own in a former year, that in a public department like the Local Government Board, there ought to be an Inquiry Office. They had not constituted one, and Sir Henry Cole thought the Society of Arts should do so. He hould be delighted if the Society could see its way to stablish an Inquiry Office on this subject, but the lifficulty which they could all easily understand was ne of ways and means. It meant a room devoted to the urpose and one or two persons, one of whom at least hould be highly qualified, and both of whom should be paid for rendering a service which would be necessary to the regular conduct of a department of that description. He was not sure that it would be within the means of the Society to undertake such an experiment, or whether Sir Henry Cole made the suggestion with any knowledge as to the intentions of the Society. He limited himself to the expression of opinion that it was a fit thing for the Local Government Department to undertake, and that if it were to do so, it would add very much to the smooth working of their own department, and to the progress of sanitation throughout the country. Then Sir Henry Cole passed on to another subject, and referred to the very interesting letter from the Duke of Sutherland to Mr. Sclater-Booth, who proposed federation of local authorities. The existing law provided for that federation as far as it could do so in the original Local Government Act, which gave power for local sanitary districts to combine in aggregate areas for some common purpose, by provisional orders requiring confirmation by Parliament. The reason why he had inserted that provision, was this. He did not say to himself that it would have a great practical effect, because you did not easily get 12 or 20 local authorities to combine and press a provisional order through Parliament, but it seemed to him to lay down a principle which might have practical results, and would at any rate have some result in further legislation at a future time. What that result ought to be he would not say at present. Then he came to Mr. Cresswell's interesting paper, and the resolution passed thereon. Mr. Cresswell's paper was upon the general subject of the impure condition of the River Thames with special reference to that part of it with which he himself was most familiar. In that resolution, again, he thought they had gone as far as it was advisible for such a Conference to go, and that the further responsibility ought to be left with the Government of the day. Now, to go back to two matters on which he had already touched, the first of which was that of National Water Supply, on which he hoped a Commission would be appointed, and the second was the proposal of the Duke of Sutherland for the federation of local authorities for the purpose of dealing with questions of the prevention of river pollution. Both of those subjects were connected with this general consideration—the necessity for making provision, for many purposes, for larger areas of Government than those which already existed. As far as the supply of water was concerned, the tendency of the scientific mind was towards water-shed areas and authorities, and he found no fault with that as a scientific view. As far as the view raised by the Duke of Sutherland was concerned, he supposed the view was simply this, that you could not conserve the purity of certain rivers without, at any rate, very much enlarging the area within which you carried out measures for their preservation. But he had another point of view to which he should like to direct attention, not for the first time. He had often said that after all this question was not a mere question of health but of local government, and he said that in the interests of health as well as in the interests of local government. In questions of health you could not drive the country but you could lead it, and you could only lead the country through representative institutions of some kind. You could educate the representatives whom those institutions brought into public action, and what he desired was this, that in a proposal of this kind, from a scientific point of view, you should not forget what he called the local government point of view; and, collating those two ideas, he was continually reminded of the importance, which he, for one, had never forgotten, of passing a measure for the formation of County Boards. That scheme for County Boards was one propounded during the time of Mr. Gladstone's Government, some six years ago, and by himself as the member of that Government charged with the subject. It had been dealt with by his successor in the Local Government Board, and by various persons in the House of Commons, but it had never gone further than the second reading, if so far. There was a great difficulty in the way, so far as the House of Commons was concerned, that there was a great objection, on the part of many people, to the construction of Boards, which they thought might not end in economy, but in additional expenditure. He was not prepared to say that they would not end in additional expenditure, but he had often used this language, that although saving was profitable, profitable expenditure was more profitable that mere saving. If you had Boards rightly constructed for large areas endowed with considerable powers, so that you might hope to attract the best men of the locality to serve on them, although you might get an increased expenditure, you would get a greater return in the shape of greater convenience, comfort, and happiness, and health of the population concerned. With regard to the question of water supply, he would not lay down any hard and fast rule or line. He did not say that the County Board of the future was to be the authority for the conservancy of all the rivers within the county; it might be advisable to enlarge the area of the conservancy and the prevention of pollution. All that he would say would be this, bear in mind that you have to construct these County Boards, and endeavour to harmonise their future with this idea of the future conservancy of rivers, and this might be done with the most perfect ease. If it were necessary to combine one or more counties for the purpose of forming a water-shed area, you had only to make it a combined authority, instead of setting up one *de novo*, and he did not believe that the difficulties would be at all serious, and, at any rate, adhering to this view, you ought not to cross the county lines in the construction of any one of these water-shed authorities. They had had experience of crossing boundary lines, and the multiplex combination of sanitary areas, and had endeavoured, by legislation, to reduce the number of those areas and simplify them; and he trusted in future, as they had of late, they would endeavour to adhere to this very simple rule, which he did not think would be found impossible of application. They should start with the administrative unit, the simplest area you had in the country, the local government area, the urban or rural sanitary district. That was an area for certain purposes of local government. He desired that it should not be too small, but when you wanted a larger area for some common purpose, the simple rule in his own mind was to have an aggregate of those smaller areas, never to divide them. You might meet with some difficulties, but depend upon it, for the sake of simplicity, in the long run, it would be better to meet them at first. If you once laid down the principle, the thing became very simple. You had these units of administrative area, and for purposes in which you required large areas you formed an aggregate of those units, it might be one county or two counties. The meeting to-day had been rather long, but he hoped not uninteresting or unimportant. He hoped the meeting would agree with him that this Conference might compare favourably with those of past years, and that gentlemen would be willing to come again next year, and again take up this useful and necessary public work.

Dr. Yeld, in proposing a vote of thanks to the Chairman, said he quite agreed with him that the Conference had been a great success; many of the papers were very valuable, and he was sure that all would agree with him that the very able manner in which the Chairman had summarised the proceedings was, in itself, a treat to everyone who had heard it.

Mr. Birkett seconded the resolution, which was carried unanimously, and the proceedings terminated.

SEWAGE FARMS.

REPLIES TO QUESTIONS ISSUED BY THE COMMITTEE.

The following is a summary of the returns furnished to the Committee in reply to questions relating to the working of sewage farms for the year 1878:—

Crewe.—Population, 25,000; rateable value, 64,656. Farm named Crewe Sewage Farm; about 260 acres in the farm. The land purchased at £3,875; annual rental of the land leased to the Corporation, £833. Amount of stock, 59 feeding cattle heifers, but the number varies; no sheep; about £45,000 spent, which includes purchase of land and construction of outfall sewers, drift culvert, &c.; the tanks accomplish settling; no precipitant is used; the settlement is distributed on the land. The Corporation works the farm itself; the produce consists of rye grass and willows. The cost of the sewers was about £10,000, included in the cost of the whole work as above. There are no purifying works; no separation of storm water. The average flow of sewage is one million gallons per day; with storm water, sometimes 20 million gallons, but impossible to give average. The effluent water is clear and free from smell. The effluent water does not pass into a river from which water is taken for drinking. The estimated rate on the rateable value (including instalments upon borrowed money) is 1s. 6d. in the pound.

Edmonton.—Population, 16,000; rateable value, £80,000. Edmonton Sewage Farm, 114 acres (8 acres for osiers, 16 acres for watercress and grass, and remainder let to a farmer who uses the sludge from the beds). Cost of purchase, £14,050; capital spent in underdraining land, £1,450; cost of three tanks, to hold 300,000 gallons each, mixing apparatus for treatment by precipitation, £2,500. (Engine-house, engines, boilers, and storage reservoir, to hold 2,000,000 gallons in time of heavy rains, and for storing night and sundry work.) The tanks accomplish clarification and deodorisation. Hillé's process, in the usual form, is adopted, and the cost (with chemicals) is £260 per annum. The whole of the settlement is used by the Local Board, and the farmer on land as manure either liquid or dry. The deposit manure is composed of precipitated matters in suspension, and partly in solution from the sewage *plus* the chemicals used. Total annual cost of labour, coals, pumping, chemicals, and everything included, £850. The Local Board manage the farm, but part of the 114 acres is let to a farmer. Watercress and osiers are most beneficially affected. The whole main drainage works of Edmonton, including some 28 miles of brick and pipe-sewers, &c., cost about £42,500. The storm water is separated to some extent. The average quantity of sewage flowing in 24 hours is about 900,000 gallons. The effluent water is pure enough for all sanitary practical purposes. It passes into a river from which the water is taken for drinking, but the discharge is below the intake. The estimated cost is 1s. per head of population. The works and system carried out give satisfaction in every respect to the local and river authorities. Effluent very good; sludge easily disposed of as good manure; osiers and watercress grown in very good condition.

Malvern Link.—Population, 2,020; rateable value, £7,875. Farm named Malvern Link; 21 acres in the farm; 14 in permanent pasture, 7 arable; annual rental, £40; the farm is leased by the Board and sub-let. The general district rate of last year, at ½d. in the £ realised £498.

Norwich.—Population about 83,000; rateable value, £239,374. Farm named Whittingham and Kirby Bedon; about 850 acres in the farm. Let on lease; annual rent, £1 16s. per acre.

Reigate.—Population at last census, 15,916, now estimated at 18,000; rateable value, £77,461 16s. 10d. Farms named (1) Earlswood and (2) New Pond. (1) contains 54 acres, (2) 85 acres; (1) six acres in permanent pasture, 16 arable, 32 under irrigation; (2) 18 acres in permanent pasture, 26 arable, 41 under irrigation; cost of purchase, £10,200; amount of stock, 3 horses, 18 bullocks; capital spent in laying out Earlswood Farm about £3,463; the cost of works upon New Pond Farm not ascertainable; paid for with other work; the cost of tanks at Earlswood, £150; at New Pond, £200. The tanks accomplish settling and screening; no precipitant is used. The settlement is principally used as manure for mangold wurzel; none is sold. The sewage deposit manure consists of the usual deposit with the waste water of a tan-yard, and silica from the roads brought down by the storm water. The cost of working the Earlswood Farm upon an average of three years, £447 15s. 8d.; of the New Pond Farm during an average of two years, £901 2s. 9d., but the latter sum comprises portion of the capital employed in laying out. The Corporation work the farms themselves. Rye grass and mangold wurzel the produce most beneficially affected. The loss upon the Earlswood Farm, upon an average of three years, £152 8s. 4d.; upon the New Pond Farm, upon an average of two years, £242 0s. 8d. Cost of the sewers which bring the sewage to the farm about £46,080; there is a partial separation of the storm water. The daily volume of sewage discharged by the Eastern Trunk sewer, and collecting the drainage of Redhill and the neighbourhood, is set at 500,000 gallons (Earlswood Farm). The same discharged by the Western Trunk sewer, and collecting the drainage of Reigate town and neighbourhood, is set at 350,000 gallons (New Pond Farm). The average quantity of sewage with storm water, about 4,000,000 at Earlswood Farm, and about 3,000,000 at New Pond Farm. The quality of the effluent water is good; it does not pass into a river from which the water is taken for drinking. The estimated cost per head of the population, 3s. 1d. yearly, inclusive of interest upon all capital expended. The estimated rate on the rateable value, 8½d. in the £.

RUGBY.—Population estimated at 8,500; rateable value, £49,000. Two farms: (*a*) Bilton (*b*) Rugby Sewage Farms; land all arable; rent of *a*, £265 and tithe; of *b*, £56. The tanks accomplish settling. The settlement is spread on the land; it is difficult to deal with it otherwise, *a* is let at £350; *b* let until lately at £79 3s. There is no separation of storm water. The effluent water is clear.

SCONITON AND PENDLEBURY.—Estimated population, 20,000; rateable value, £66,000. The farm is unnamed; it consists of 31 acres 2 rods 32 perches, all meadow land; the annual rent is £158 10s. It is proposed to spend £2,800 upon the farm; the arrangements are incomplete as yet. The settlement is spread on the land by the farmer. The farm is not worked by the Local Board, but is let to a farmer at a rent of £96 per annum. The description of produce most beneficially affected is hay grass. The loss is about £60 per annum. The storm water is separated by storm overflow. The effluent water is pretty clear; it does not pass into a river from which the water is taken for drinking. Estimated rate on the rateable value, £5,231. The sewage schemes for the district are not yet complete, neither is the farm.

SOUTH MOLTON, DEVON.—Population about 4,000; rateable value, £13,583 12s. 6d. Farm named Fordouen; 73 acres in the farm, 33 in permanent pasture, 40 arable; all under irrigation in rotation. Cost of purchase, £3,300. Leased for 14 years, at £167 10s. per annum for first three years; £177 10s. for next four years; and £187 10s. to end of term. Cost of the sewers, which bring the sewage to the farm, about £400. There is a separation of the storm water. No effluent water passes into a river from which the water is taken for drinking.

STOKE-UPON-TRENT. — Population, 1,700; rateable value £58,400. Sideway Farm, about 60 acres; almost entirely pasture, and it is intended to adopt precipitation, irrigation, and downward filtration as far as practicable. Cost of purchase, £200 per acre, £1,000 to be paid in addition for the buildings on the farm.

WEST DERBY.—Population estimated at 32,263; rateable value, £174,514. Farm named West Derby Sewage Farm, Fazakerley: 207 acres in the farm, the whole being arable; about 189 acres are under irrigation; cost of purchase was £36,134 18s. 7d.; there is no stock, but grazing is occasionally let for horses and sheep; capital spent in laying out the farm and its works, £16,858 13s. 5d.; the cost of tanks, £6,740 18s. The tanks are used to receive sewage from eastern portion of district, previous to pumping on to land; no precipitant is used. The settlement is used for top dressing, &c. The cost of working the farm for the official year ending 25th March, was £3,003 14s. 6d.; the cost of maintenance of works is nominal at present. The Local Board work the farm itself. Rye grass, mangolds, cabbage, and savoys are most beneficially affected. The profit on working for the year ending March, 1879, was £632 16s. 3d., in addition to stock in hand valued at £238 17s. 4d.; this is exclusive of any payments on account of interest or instalments of principal for purchase of tanks, laying out, and bringing sewage to farm. The cost of sewers which bring the sewage to the farm, £5,294 0s. 9d.; the storm water from houses and some of the roads is admitted to the sewers, but the Board are taking steps to divert the storm water of the roads into the natural watercourses of the district. The effluent water goes into the River Alt, but the water of this river is only used for cattle.

WOLVERHAMPTON.—Farm named Barnhurst: total area of land acquired for sewage utilisation 232 acres, 1 rood 24 perches, about 97 acres of which are occupied with sewage works, fallow land, &c. £36,7[illegible] has been expended in the purchase of land, and about £24,134 on works for dealing with the sewage on the estate. The farm was let up to Michaelmas, 1873, to a tenant, who paid during the last year of his tenancy, £658 15s. 11d. as rent. It is now worked by the Corporation. The profit on working for the year 1878-9 amounted to £336 12s. 8d., as against £1,205 1s. 4d. in 1877-78; £1,007 17s. 7d. in 1876-7; £1,048 16s. 5d. in 1875-6; and £645 6s. 6d. in 1874-5. Estimated rate 8d. in the £.

SCHEDULE OF QUESTIONS PROPOSED.

1. Name of place.
2. Population.
3. Rateable value.
4. Name of the farm.
5. Number of acres in the farm.
6. Number of acres in permanent pasture.
   „ „ arable.
   „ „ under irrigation.
7. Cost of purchase or annual rental of the farm.
8. Amount of stock, specifying sheep and cattle.
9. Capital spent in laying out the farm and its works.
10. Costs of tanks of any kind.
11. What the tanks accomplish—settling, screening, &c.
12. Any and what kind of precipitant used? If so:—
    a. Method of application.
    b. Cost.
13. What is done with the settlement?
    a. If sold, what quantity of solids.
    b. What amount realised.
14. Cost of producing the deposit manure in a saleable condition.
15. What is the composition of the sewage deposit manure?
16. Cost of working the farm—labour, manure, &c.
17. Cost of maintenance of works, &c.
18. Does the Corporation work the farm itself?
19. Or, is the farm leased, and what rental is obtained?
20. What description of produce is most beneficially affected?
21. Financial results:—
    a. Profit.
    b. Loss
22. Cost of the sewers which bring the sewage to the farm.
23. Are there any purifying works? If so, cost of
    a. Construction.
    b. Maintenance.
24. Any separation of the storm water?
25. Average quantity of sewage flowing in 24 hours:—
    a. With storm water.
    b. Without storm water.
26. What is the quality of the effluent water?
27. Does the effluent water pass into a river from which the water is taken for drinking?
28. Estimated cost per head of the population.
29. Estimated rate on the rateable value.
30. Any explanatory remarks.

THE THAMES CONSERVANCY BOARD.

The following account forms a Supplement to "Notes on Previous Inquiries" on Water Supply, issued by the Society of Arts, 1878. The thanks of the Society are due to Mr. Howard, librarian of the House of Commons, to Mr. Overall, of the Guildhall Library, and Mr. Gough, of the Thames Conservancy Board, for kind assistance rendered in its compilation.

In consideration of the fact that the purity of the Water Supply of London, and questions connected with the POLLUTION of the THAMES, have lately attracted an increasing amount of attention, it has been thought useful to compile and issue an account of the Thames Conservancy Board, which, among its other functions, now has control over the pollution of the Thames and its tributaries.

The following pages are arranged on the same general plan as the "Notes on Previous Inquiries,"[*] prepared in connection with the Congress on National Water Supply, held in May, 1878. In referring to volumes of Parliamentary papers, the arrangement which is followed is that of the House of Commons library, in the manner explained on p. 1 of the "Notes."

INTRODUCTORY.

From "time immemorial" the Mayor and Corporation of London were "conservators" of the Thames down to the year 1857, when the Thames Conservancy Board was established, by an Act dated 17th of August in that year.

The powers of the Board have been augmented, and its range of supervision extended, by subsequent acts, especially with regard to prevention of POLLUTION. Down to the year 1866 indeed the Board was, as the old conservators were, mainly occupied with keeping the river channels clear, granting leases for embankments, jetties, &c., controlling navigation and fisheries, &c., but in that year an Act was passed which, in Sec. 63-4, gave them powers to PREVENT persons or corporations from PASSING SEWAGE INTO and OTHERWISE POLLUTING the Thames. Subsequent Acts extended this power till it now applies to the whole course of the river and its tributary streams for 10 miles on each side of the main river.

The Rivers Pollution Prevention Act, which applies to all Britain, was not passed till August, 1876 (that is ten years after the powers against pollution were granted to the Thames Conservancy), and this in no way affects the Thames Conservancy Board, as, by § 18 of that Act, it is provided, "Nothing in or done under this Act shall extend to interfere with, take away, abridge, or prejudicially affect any right, power, authority, jurisdiction, or privilege given by 'The Thames Conservancy Acts, 1857 and 1864,' or by 'The Thames Navigation Act, 1866,' or by the 'Lee Conservancy Act, 1868,' or by any Act or Acts extending or amending the said Acts, or either of them, or affect any outfall or other works of the Metropolitan Board of Works (although beyond the metropolis) executed under the Metropolis Management Act, 1855, and the Acts amending or extending the same, or take away, abridge, or prejudicially affect any right, power, authority, jurisdiction, or privilege of the Metropolitan Board of Works."

The powers of the Thames Conservancy Board are, therefore, clearly laid down in the Acts of Parliament relating to it, and are not modified by any general Acts.

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[*] Published by Bell and Son, York-street, Covent-garden.

THE CONSERVANCY PRIOR TO 1857.

The early history of the conservancy, or, as Stow calls it, the jurisdiction, of the Thames, is, by the Conservancy Acts, made, to a great extent, a matter of antiquarian interest, since the Thames Conservancy Board derives its power, not as the Corporation up to 1857 did, from custom and Royal charters, &c., but clearly and definitely from the Acts.

Those who are interested in the antiquarian aspects of the Corporation's rights and powers over the Thames, transferred now to the Conservancy Board, will find an account, down to 1720, in Strype's Stow, chapters vii. and viii. [A Survey of the Cities of London and Westminster ..... written at first in the year MDXCVIII. by John Stow ..... augmented by the author and afterwards ..... others ..... now, lastly, corrected, improved, and very much enlarged, and the survey and history brought down from 1633 ..... to the present time ..... by John Strype, M.A. ..... In six books. ..... MDCCXX.] (This edition is in 2 vols.)

The "Liber Albus" goes back further than Stow does, as the statutes and ordinances of Brut, "the first monarch of Britain," is quoted. (Riley's edition, p. 497. § Statuta et Ordinationes de Kydellis et Tryinkis in Thamisia et Medwaye ammovendis.)

Stow, however, gives apparently all that is of importance in the report of a charge made in 1616, in which the then history of conservancy rights are summed up.

Book I., chapter viii. [p. 34, of Strype's edition] records that:—"In the year 1616, on Wednesday, being the third of July, Sir John Jones, Knight, Lord Maior of London, and conservator of the River Thames and waters of Medway, assisted and accompanied by ..... &c., &c. ..... took barges at Belingsgate, and within a few hours arrived at Gravesend, in Kent, where a session for the conservacy of the saide river was kept before the Lord Maior and his forenamed assistants, at which time and place a jury of freeholders of the said county, being sworn to enquire of all offences committed in any part of that river within the said county, Master Common Serjeant delivered them a charge to this effect."

Then follows a report of the charge in which the Common Sergeant set forth that the jurisdiction of the City of London in the River Thames, from Staines-bridge, westward, to the points of the river next the sea, eastwards, appeared to belong to the City in point of *right*, and in point of *usage*.

The point of right is set forth on ten grounds:—

(i.) By prescription.
(ii.) By allowance in *eire*.
(iii.) By ancient charters.
(iv.) By Acts of Parliament.
(v.) By inquisitions.
(vi.) By decrees upon hearing *coram rege ipso*, and in *camera stellata*.
(vii.) By Letters Patent.
(viii.) By proclamations.
(ix.) By report of the King's Council Learned.
(x.) By a *quo warranto*.*

The points of usage are set forth under six heads.

(i.) By ancient ordinances.
(ii.) By punishment of offenders.
(iii.) By writs and precepts.
(iv.) By accounts for charges of searches.
(v.) By commission.
(vi.) By continual claim ever since 37, Hen. VIII., when the Lord High Admiral first interrupted the City to exercise her authority below London Bridge.

Each of these is set forth at length with reference to records.

The charters quoted are from Richard I., King John, Henry III., and Edward III.

All the various charters can be consulted in "Luffman's edition of the City Charters," from William the Conqueror down to George II. They are also in abstract in Norton's "Commentaries," and, briefly, the important ones are given in the second report of the Royal Commission on the Municipal Corporations in England and Wales.

The first charter of Charles I. is an "inspeximus" charter, which includes all previous ones.

It may interest some to be reminded that there was shown at the Caxton Exhibition the statute of Henry VII. relating to the conservancy of the Thames, printed by Caxton, in what Mr. Blades, in his biography of Caxton, calls type No. 6. (It was in Class A., 153.)

Most of the charters relating to the Thames Conservancy have reference primarily to the object of clear navigation, but some have referred to sources of income, as, for example, the first charter of James I.

This Charter refers to the office of bailiff, and to that of the conservation of the water of the Thames as having been, time out of mind, possessed by the Mayor and Commonalty, and exercised by he Mayor or his Deputy for the time being, from Staines Bridge to Yendall, otherwise Yenland or 'enleet, and in the River Medway, and upon every bank, shore, and wharf, within those limits, ogether with all wages, rewards, fees, and profits belonging to the office. It also refers to the office f *Measurer*, as having been possessed and exercised in the same way, of all coals and grain; also of lt, and all kinds of fruit and vegetables, and of all other goods and merchandises.*

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* A writ, ordering them to show by what warrant they pretended to be a corporate body.

Without attempting to quote or to give a *résumé* of these charters on conservancy, there are some ew points of interest as bearing on POLLUTION, in the Corporation records, in illustration of the nactments of Lord Mayor as Conservator.

In xvi. of RICHARD THE SECOND, *A.D.* 1390, It is enacted, that all filth upon the side of *Thames* ext the house of *Robert de Partis*, shall be utterly removed; and that in some place, before *Easter* hen ensuing. That the butchers of *London* do build convenient and fit houses, whereunto they may, rom time to time, bring all their ordure, entrails, and other filth, and the same in boats, carried in he middle of the *Thames*, and there cast the same at a full water, when it first beginneth to ebb; and, rther, that no person do throw or cause to be thrown, or laid, any filth or odure, muck, rubbish, r laystage, in the same water of Thames, of the one side or the other, between the Palace of *Westinster*, and the *Tower of London*, on loss of £10. [*William Standon, Mayor.*]"†

Again, 240 years later on:—Among the articles ordained by Sir Robert Ducie, Lord Mayor in 630, "to be enquired upon by the jury for the river Thames eastward" is the following:—

"27. *Item*: You shall further enquire, and true presentment make, whether any butcher, brewer, nn-keeper, or any other person or persons, as well within the City of *London* as in any other county own, or village (as far as the liberty of the Lord Mayor extendeth) have cast or put into the said iver any paunches, grains, horse-dung, or other rubbish, soil of filth, whatsoever, to the very great nnoyance and hurt of the said river, on pain of imprisonment, and further fine, at the discretion of he Lord Mayor of *London*. If you know any such, you shall present them."‡

One of the latest writers on the subject, before the Chancery suit was commenced in 1844 (see next age), was Pulling. In his "Practical Treatise on the Laws, Customs, and Regulations of the City nd Port of London, as settled by Charter, Usage, By-law, or Statute," 1842, he devoted chapter ix. to the River Thames and the Port of London. Here may be found ready to hand an account of he old Conservancy as it was just before the Board was established.

He sums up the duties of the Conservators of the Thames, showing they had the control and egulation of the fisheries, the seizing unlawful nets, regulating watermen and lightermen employed n the river, and the shipping in the port, and fixing posts in the river for the conveniency of such hipping; removing obstructions occasioned by wears and steps; cleansing the river; directing to what places, and the manner in which ballast should be taken out of the river; repairing its banks nd breaches; licensing and permitting wharfs, piers, stairs, and other innocent projections, and eceiving rents therefore, and removing such as are unlicensed; erecting and maintaining public stairs, nd removing illegal ones; giving orders respecting floats upon the river; granting licenses to erect mill and water works, and holding Courts of Conservancy, and punishing offenders.

In compliance with ancient usage, the Lord Mayor, accompanied by the Recorder, and other civil fficers, still held in person eight Courts of Conservancy in the year; two for each of the counties of Middlesex, Surrey, Kent, and Essex, and occasionally a Court in London, into each of which place the jurisdiction extended, reaching from Staines to Yantlet Creek on the Thames, and from Colew or Creek to Cockham Wood in the Medway, and various officers were appointed by the Corporation to see the laws and regulations of the river carried into effect.

The more recently acquired duties of the Conservancy in regard to harbour masters, regulation of speed of steam vessels, &c., are also given in this history.

These matters, however, are apart from the control of POLLUTION, and are here just briefly referred to in order to point out the wide range of subjects the Conservancy had to control.

The Select Committee of the House of Commons on the state of the Port of London, 1836, reported as follows:—

1. That it appears to this Committee that the navigation of the river Thames in the Port of London has for a great length of time been subjected to serious and increasing obstructions by which the maritime approach to the Metropolis has been impeded, the shipping exposed to injury and needless detention, and that frequent accidents have occurred, several of which were attended with the loss of human life

3. That the Committee are of opinion that the various conflicting jurisdictions and claims of the Admiralty, the Trinity House, and the Corporation of the City of London over the Thames below the bridges, have had a most injurious effect upon the interests of navigation, and that it is desirable that they should be consolidated and vested in some one responsible body.

The Royal Commission on the Corporation of London, 1854, in their report stated (p. xxvi):—"The power and duties of conservancy are divided into two branches, those above and those below London Bridge.

"Both classes of power are regulated by various Acts of Parliament; they are exercised by a Committee of the Common Council, called the Thames Navigation Committee, and by several officers appointed by the Corporation.

"The conservancy of the river has already been the subject of Parliamentary investigation, and many opinions respecting it were expressed by the witnesses whose evidence we received."

[They go on to recommend that the navigation of the Thames should vested be in a Board.]

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* Norton, p. 390. † Binnell, p. 124. ‡ Griffiths, p. 80.

THE CIRCUMSTANCES CONNECTED WITH THE ESTABLISHMENT OF THE BOARD.

A full account of the circumstances which led to the establishment of the Thames Conservancy Board would occupy much space. Among other details there was a protracted Chancery suit, from February, 1844, till September, 1856, between the law officers of the Crown and the Corporation, as to the right to the banks of the Thames between high and low water, so far up as the tide flows. The case for the Crown was based on the principle that all the coast, with its bays, inlets, and tidal rivers, belonged to the Crown between high and low water mark; that for the Corporation, was based on the fact that the Mayor had been Conservator of the Thames from time immemorial. The outcome of the law suit was the Thames Conservancy Board.

Those who wish to look up the whole history of it will find entries in the Corporation records, the account of the Chancery proceedings, Mr. Pemberton's evidence given before the Royal Commission "to inquire into the existing state of the Corporation of the City of London, 1854," and the Thames Conservancy Act, 1857, and the report of the Select Committee of the House of Commons on the Thames Conservancy in 1863.

An abstract of some of these records will suffice to set forth the main points of the case.

In his evidence on December 2, 1853, Mr. E. L. Pemberton, solicitor to the Board of Land Revenue, said it is upwards of 16 years since his attention was first directed to the question of the title to the bed and shores of the River Thames. The circumstances which led to it were these:—The Corporation of London had, for a very long time, he believed immemorially, held the office of Bailiff and Conservator of the river. In the year 1837, the Solicitor to the Admiralty called upon him, and he drew his attention to an Act of Parliament which had been passed in the previous session (the session of 1836), for constructing a pier and other works at Greenwich, which Act of Parliament contained a clause directing the payment of a fine and an annual rent to the Corporation of London for the liberty of digging the foundations for that pier upon the shores of the Thames. At the same time there was a Bill in progress through Parliament to amend and extend the Greenwich Pier Act; and it appeared to him that the Corporation of London, in the exercise of their office of Conservators were usurping rights which could belong only to the owners of the soil. . . . . . After a correspondence and interviews, deputations, &c., clauses were settled by which the rights of the Crown in respect of its property in the soil, and the rights of the City in respect of the Conservancy, were recognised . . . . . At the same time an embankment of the river was needed for the new Houses of Parliament. . . . . . . Mr. Pemberton thereupon undertook an inquiry into the nature of the rights to the soil and shores of the river. After collecting evidence, he took the opinion of the Attorney and Solicitors General; they considered the evidence in favour of the Crown preponderated, and advised that the Crown should not voluntarily enter into litigation, and so no proceedings were instituted. This was in 1837.

In the beginning of 1843, reports appeared in the newspapers of proceedings in the Court of Common Council, by which it appeared that the Corporation had granted, or were about to grant licenses to embank portions of the river, and that they were granting such licenses not only in the character of Conservators, but in the assumed character of owners of the soil of the river.

Mr. Pemberton then wrote to the City Solicitor for copies or particulars of the licenses which had been granted, or were about to be granted, and received one which had been granted to Mr. Cubitt or an embankment in the Isle of Dogs. The license did not contain any actual grant of the strand or soil of the river, but it professed to give free permission to Mr. Cubitt to embank it, with a covenant that he should quietly hold the embankment, &c., &c.

Mr. Pemberton then consulted the Attorney-General and Solicitor-General of the day. They were of opinion that the claim of ownership of the soil of the river openly made should be set at rest, and that an information should be filed in the Court of Chancery against the Corporation and the grantees of the Corporation to embank, praying that the rights of the Crown and the Corporation respectively might be ascertained and declared, and that, if it were necessary to determine such rights by issues at law, such issues might be tried under the direction of the Court. That opinion led to the information being filed. Mr. Pemberton gave his evidence in 1853, ten years after the first steps towards the case had been taken, and while from year to year it was still continuing.

On the information being filed, notice was sent to the Corporation, the reception of which is thus recorded:—

Minutes of Proceedings of the Court of Common Council, 1844.

March 14.—The Town Clerk laid before the Court a report of Mr. Solicitor, relative to proceedings in Chancery, at the suit of the Commissioners of Her Majesty's Woods, Forests, &c. as to the City's right to the soil and bed of the River Thames, which was read.

This consisted of a letter from the City Solicitor, addressed to the Common Council, certifying that he had received from the solicitors to the Commissioners of Her Majesty's Woods, &c., a communication announcing that they had "caused an information to be filed against the Corporation of London and sundry persons to whom the Corporation have given licences to embank, praying that the rights of Her Majesty and the Corporation respectively in the strand and soil of the Thames may be ascertained and declared under the decree of the Court.

A Committee was appointed and empowered to confer with Her Majesty's ministers and others upon the subject.

30 April, 1844.—The Committee reported on a conference with Sir Robert Peel, which led to no atisfactory result, and the City's solicitor was directed to provide (as far as might be necessary) for the defence of the rights of the Corporation.

There are many entries of the work of this committee.

March 13, 1845.—Resolved—The Select Committee should be made a Ward Committee.

April 3.—The Ward Committee was appointed.

In successive years reports of this Committee are to be found.

The following dates may be of use to those who wish to learn more fully the share the Common Council took in the negociations:—

Reports of the Common Council, September 17, 1857.

"We, whose names are hereunto subscribed, of your Consolidated Committee, appointed by your Honourable Court on the twenty-second day of *May*, 1846, with full power to confer with Her Majesty's Government, and others, upon such of the matters specially referred to the several committees of the Corporation as your Committee should deem expedient, and to report from time to time o this Honourable Court, to whom, on the seventeenth day of *December*, 1846, it was referred, to prosecute a petition to the House of Commons for a Bill in respect of the Conservancy of the River *Thames*; to whom, on the seventeenth Day of *December*, 1847, it was referred to prosecute a petition o the House of Commons for a Bill relating to the Conservancy of the River *Thames;* to whom, on he fourteenth day of *December*, 1848, it was referred to prosecute a petition to the House of Commons or leave to bring in a Bill relating to the Conservancy of the River *Thames;* to whom, on the fifth day of *December*, 1850, it was referred to prosecute a petition to the House of Commons for a Bill elating to the Conservancy of the River *Thames;* to whom, on the eighteenth day of *December*, 1851," &c., and so on for each year, up to the settlement of the case.

The preamble to the Thames Conservancy Act, 1857, also gives an account of the circumstances connected with the establishment of the Board, thus:—

Whereas the preservation and improvement of the River Thames is of great national importance: And whereas the Queen's most Excellent Majesty, in right of her Crown, is or claims to be seised of the ground and soil of the seas around the United Kingdom of Great Britain and Ireland, and of the shores thereof so far as the sea flows and reflows between the high and low water marks at ordinary tides, and also of all rivers, creeks and arms of the sea, and the ground and soil thereof, and of the shores of the same respectively, between the ordinary high and low water marks from the mouths or entrances to the same from the main sea upwards, and into the country so far as the water flows and reflows at such ordinary tides, and of all the ports and havens of the United Kingdom, save and except only such parts of the said seas and sea-shores, rivers, creeks, and arms of the sea respectively, and of the shores thereof, and such ports and havens respectively, as are held by or are vested n certain bodies politic and corporate, and others by prescription, and by or under grants from the Queen's Majesty or any of her predecessors, or by or under Acts of Parliament, and the Conservancy of such ports and havens, rivers, creeks, and arms of the sea as aforesaid, except as aforesaid, and except where the same is held or is vested in certain bodies politic and corporate, and others by prescription or otherwise, belongs to the Lord High Admiral or Commissioners for executing the office of Lord High Admiral of the United Kingdom: And whereas the Mayor and Commonalty and Citizens of the City of London have, from time immemorial, had and exercised by the Mayor of the said City for the time being during his Mayoralty, or by his sufficiet deputies, the conservation of the River Thames between Staines, in the County of Middlesex, and Yenleete, in the County of Kent: And whereas an Act was passed in the fourteenth year of the reign of King George the Third, &c.

Then are recited the various Acts from that date relating to the Thames Conservancy, which are as follows (in the order in which they are recited):—14 G. 3. c. 91—17 G. 3. c. 18—50 G. 3. c. cciv.—2 G. 3. c. xlvi.—54 G. 3. c. ccxxiii.—5 G. 4. c. cxxiii—8 & 9 Vict. c. i.—39 G. 3. c. lxix.—42 G. 3. . xlix.—43 G. 3. c. cxxiv.—45 G. 3. c. lxiii.—47 G. 3. Sess. 2., c. xxxi.—10 G. 4. c. cxviv.—0 G. 4. c. cxxx.—4 & 5 W. 4. c. 32.

[These Acts have reference mostly to improving navigation, to "rendering more commodities and better regulating the Port of London," and to giving power to raise money for works and regulate olls and rates, but not to POLLUTION.]

The preamble then continues:—

And whereas a suit has been instituted by her Majesty's Attorney General, on behalf of Her Majesty' gainst the Mayor and Commonalty and Citizens, for the purpose of ascertaining and determining the rights of er Majesty and of the Mayor and Commonalty and Citizens in the ground or soil and bed of the River Thames nd the shores thereof, so far as the tide flows and reflows in the said river: And whereas an Agreement has been entered into for terminating the said suit, in the words and figures following:—

"Articles of Agreement made and entered into this 18th day of December, 1856, between the Queen's most xcellent Majesty of the first part, the Honourable Charles Alexander Gore, Commissioner of her Majesty's

Woods, Forests, and Land Revenues, of the second part, and the Mayor and Commonalty and Citizens of the City of London of the third part."

Whereas the Mayor, and Commonalty, and citizens of the City of *London* are Conservators of the River *Thames* from *Staines* to *Yantlet*, and exercise that authority by the Lord Mayor for the time being, as Conservator of the said River *Thames*, within the said limits: And, whereas the said Mayor, and Commonalty, and citizens claim to exercise rights of ownership on the bed and soil of the said river; and in the month of February, 1844, Her Majesty's Attorney-General did, on behalf of Her Majesty, exhibit an information in the High Court of Chancery, against the said Mayor, and Commonalty, and citizens, *Henry Alworth Merewether*, town clerk of the said city, and others, for the purpose of establishing the title of Her Majesty, in right of her Crown, to the bed and shores of the River *Thames*, within the flux and reflux of the tides, and to certain encroachments upon such shores, and for the other purposes in the information mentioned: And, whereas the said Mayor, and Commonalty, and citizens, and the several other Defendants to the said information, put in their several answers thereto, and the cause is now at issue: And, whereas it is desirable to put and end to such litigation, and the said Mayor and Commonalty, and citizens are ready and willing to acknowledge the title of Her Majesty to the bed and shores of the River *Thames*, as alleged by the said information, and it would be to the public benefit, and would facilitate the discharge of the duties of the office of conservator of the said river, that the bed and soil of the said river should, upon certain terms and conditions hereinafter set forth, be vested in the said Mayor, and Commonalty, and citizens, in trust for the purposes hereinafter mentioned.

* * * * * * * * * * * * *

Now, these presents witness that the said Mayor and Commonalty, and citizens of the City of *London*, do wholly withdraw all claim to the ownership of the bed and soil of the River *Thames*, so far as the tide flows and reflows therein, and do admit that the Queen's most excellent Majesty, in right of her Crown, is seised to herself, her heirs, and successors, of the fee simple and inheritance in possession of the bed and soil of the River *Thames*, within the flux and reflux of the tides, &c., &c.

The terms of the agreement occupy from page 2348 to page 2353.

Shortly stated they are—

Firstly. The suit shall cease.

Secondly. The Commissioners of Woods and Forests shall convey, before the 1st of March next, "the estate, right, title, and interest of Her Majesty in right of her crown of in and to the bed and soil of the River Thames, within the flux and reflux of the tides bounded eastward by an imaginary line to be drawn from the entrance to Yantlet Creek, in the County of Kent, on the southern shore of the said river, to the City Stone opposite to Canvey Island, in the County of Essex, on the northern shore of the said river, and all encroachments, embankments, and enclosures therefrom or thereupon, except such parts thereof as are hereinafter specified.

Thirdly. Provision is made for not interfering with Government property.

Fourthly. The Mayor, Commonality, and Citizens shall give an yearly account to Commissioners of Woods and Forests, and shall pay to the Crown one-third of moneys received in each year, the remaining two-thirds to be set apart "for improving the navigation of the said river, and the banks thereof within the limits aforesaid."

The remaining six paragraphs deal with the right to demand payments for leases, with the supervising right of the Admiralty in certain matters, the due delivery of schedule of property, &c.

The preamble then continues:—"And whereas, by an indenture dated the 24th day of February, 1857........the said Charles Alexander Gore........did grant and convey unto the Mayor, Commonality, and Citizens of the City of London and their successors, as Conservators of the River Thames, all the estate, right, title, and interest of Her Majesty in right of her Crown of, in, and to the bed, soil, and shores of the Thames, within the flux and reflux of the tides, &c., &c."

* * * * * * * * *

The preamble then continues:—"That whereas, for the better and more safe navigation," shoals should be removed, &c. . . . . "and whereas it is expedient the whole regulation should be UNDER ONE UNIFORM MANAGEMENT," &c.

The preamble goes on to state that the powers vested, &c., in the City or Common Council should be transferred to the Conservators appointed by the Act.

Then follow the clauses of the Act.

NOTE.—The above is the account of the origin of the dispute between the Crown and the Corporation, given by Mr. Pemberton in his evidence before a Select Committee of the House of Commons. The present City Solicitor, however, has informed the Secretary that the suit arose "in consequence of the City having proceeded to erect steam-boat piers for the accommodation of the river traffic."

THE ESTABLISHMENT OF THE BOARD.

THE FIRST ACT, 1857.

The clauses of the Act of 1857 give the establishment of the Board, and define its duties and its powers.

The Act is entitled "An Act to Provide for the Conservation of the River Thames, and for the Regulation, Management, and Improvement thereof." [17th *August*, 1857.]

Clause I gives explanations of terms used, but the word POLLUTION does not occur.

Clause II provides for appointment of twelve Conservators, to be called "The Conservators of the River Thames."

Clause III provides that the appointments are to be as follows:—

1 Lord Mayor. }
2 Aldermen. } Of the City of London.
4 Common Councilmen. }
1 Deputy Master of Trinity House.
2 Appointed by Admiralty Commissioners.
1 „ „ Privy Council.
1 „ „ the Corporation of Trinity House of Deptford, Strond.
12

Clauses IV to XI refer to details of elections.

Clauses XII to XLIII refer to the internal arrangements of the Board.

Clauses XLIV onwards to LI refer to power to make bye-laws.

Clause LII provides that the powers of the Queen and of the Corporation are to be vested in the Conservators.

The next clauses refer to letting piers, landing places, taking tolls, building piers and toll-houses, appointing harbour masters, raising sunken vessels, fixing buoys and beacons.

XCVIII gives power "from time to time, as occasions may require, to dredge, cleanse, scour the River Thames"........and to abate and remove "all impediments, obstructions, and annoyances, and all nuisances and abuses whatsoever in the River Thames, or on the banks and shores thereof, which may now or at any time hereafter be injurious to the River Thames, or obstruct or lead to obstruct the free navigation thereof." [Note the words "cleanse" and "nuisance."] Power is given for apparatus for humane purposes for shortening bends of river and preventing ballast from being thrown into Thames.

"CII. Every person who shall unload, put, or throw into any part of the River Thames, or on any shore or ground below the high-water mark of the River Thames any rubbish, earth, ashes, dirt, mud, soil, or other matter, or allow any offensive matter to flow into the River Thames, shall forfeit for every such offence any sum not exceeding twenty pounds." [Note.—Any offensive matter.]

CIII. Annual account to be sent to Commissioners of Woods and Forests.

CIV. One-third of all moneys to be paid to Crown.

CV., &c. Certain works to be under control of Admiralty.

CIX. Trinity Corporation to remove shoals when required by Conservancy.

The succeeding clauses are mainly details of money affairs.

CLXIII. Accounts to be yearly laid before Parliament.

CLXIV., &c. Protecting rights of Crown, Trinity House, Commissioners of Sewers, Metropolitan Board of Works, Dock Companies, Companies of Abbey Mill River, Commissioners of Works, the Crown in River Medway, the Duchy of Cornwall, the Duchy of Lancaster, the Inner and Middle Temple, the Marquis of Salisbury, the Regent's Canal Company, Trustees of River Lea.

CLXXX. Short title, "The Thames Conservancy Act, 1857."

CLXXXI. The Act to come into operation 29th day of September, 1857.

THE DEVELOPMENT OF THE BOARD.

The history of the development of the Board in its NUMBERS, and in the EXTENSION of its JURISDICTION as regards the LENGTH of the Thames, and the WIDTH on each side of the banks, will be seen from the following extracts from the Acts:—

The Second Act, 1864.

The second Act, among other matters, provided for an addition to the number of the Conservators.

It is entitled "An Act to Amend the Laws relating to the Conservancy of the River *Thames*; and for other purposes relating thereto." [29th *July*, 1864.]

The preamble sets forth:—

"Whereas it is expedient to provide for the addition to the Conservators of the River *Thames* of a certain number of elective Conservators, and to discontinue the exclusive rights of the *Trinity House* in relation to the supply of ballast in the River *Thames*, and to amend the Watermen's and Lightermen's Amendment Act, 1859 (hereafter in this Act called the Watermen's Company's Act), and to make better provision and regulation of the fisheries in the River *Thames*, and in other respects to amend the laws relating to the River *Thames*, and particularly the *Thames* Conservancy Act, 1857 (hereafter in this Act called the Principal Act), &c.

There are two clauses on the subject of the additions:—

5. In addition to the twelve Conservators acting under the principal Act (to whom the designation

"the nominated Conservators," when hereafter used in the Act, refer), there shall be six Conservators elected under this Act, who shall severally have and be subject to all the same or the like powers, functions, duties, privileges, &c.

6. The six additional Conservators (hereafter in this Act called elective Conservators) shall, subject and according to the provisions of this Act, be elected by the following classes of electors (of which classes respectively they shall be deemed representatives), namely—

"2 by owners of shipping registered in the Custom House books of the Port of *London* (hereafter in this Act called ship-owners):
"1 by owners of steamers surveyed and certificated as passenger steamers by the Board of Trade (under the Merchant Shipping Act, 1854, and Acts amending the same), and plying on the River *Thames* not seaward of Gravesend (which steamers are hereafter in this Act called passenger steamers):
"2 by owners of lighters and steam-tugs used on the River *Thames*:
"1 by occupiers of docks on the River *Thames* established under Charter or Act of Parliament
— and of legal quays and sufferance wharfs on the River *Thames* appointed by the Com-
6 missioners of Customs (hereafter in this Act called dock-owners and Wharfingers)."
—

THE THIRD ACT, 1866.

The third Act added five more Conservators to the Board, extended the control of the Conservators from Staines to Cricklade, and by section 63 made direct provision against pollution.

It is entitled "An Act for vesting in the Conservators of the River *Thames* the conservancy of the *Thames* and *Isis* from *Staines*, in the County of *Middlesex*, to *Cricklade*, in the County of *Wilts*; and for purposes connected therewith." [6th *August*, 1866.]

The preamble sets forth:—

"Whereas the preservation and improvement of the stream bed and banks of the upper part of the *Thames* is an object of great local and public importance:

"And whereas by the Acts described in the first schedule to this Act (to which Acts expression 'the Upper Navigation Acts' where used in this Act refers, and which Acts, or some of them, are severally referred to in this Act by the respective short descriptions in the same schedule contained), certain powers for the maintenance and improvement of the navigation of the *Thames* from *Staines*, in the County of *Middlesex*, to *Cricklade*, in the County of Wilts, were vested in Commissioners (in this Act called the Upper Navigation Commissioners):

"And whereas by the Upper Navigation Act of 1795, the following persons are appointed the Upper Navigation Commissioners, namely,—[Here follows a list of the persons and members of corporate bodies who were *ex-officio* members of the Conservancy, and a statement of the property qualification which carried with it the right of a seat at the Conservancy Board.]...... And whereas the Upper Navigation Commissioners thus appointed are inconveniently numerous, and not being a body corporate, they are ill constituted, &c....... And whereas it is expedient, with a view both to economy and efficiency, that the whole of the navigable parts the *Thames* be placed under one management, &c......... And whereas it is expedient that provision be made in this Act for preventing the pollution of the *Thames* between *Cricklade* and *Staines*, and the application for another Act for preventing the pollution of the *Thames* between *Staines* and the western boundary of the district under the authority of the Metropolitan Board of Works, be made to Parliament by the Conservators.........And whereas the companies constituted for supply water within the Metropolis, and drawing water for that purpose from the Thames........have in consideration of the benefits that will accrue to them from this Act, and the other Act so to be applied for, consented to contribute as in this Act provided. And whereas," &c.

Clauses 3 to 24 give details respecting the election of five additional conservators.

By clauses 6 and 7 it is enacted that
1 is to be appointed by the Board of Trade.
4 are to be elected by such persons as for the time being respectively possess some one or more
— qualifications required for upper navigation commissioners.
5
—

52. The Conservators shall cause the surface of the *Thames* to be (as far as is reasonably practicable) effectually scavenged, in order to the removal therefrom of substances liable to putrefaction.

N.B.—The following is the first clause referring to Pollution.

63. From and after the passing of this Act it shall not be lawful for any person to do any of the following things, namely—

(1.) To open into the *Thames* any sewer, drain, pipe, or channel with intent or in order thereby to provide for the flow or passage of sewage, or of any other offensive or injurious matter:

(2.) To cause or, without lawful excuse (the proof whereof shall lie on the person accused) to suffer any sewage or any matter aforesaid to flow or pass into the *Thames* down or through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose:

(3.) To open into any river, stream, cut, dock, canal, or watercourse communicating with the

Thames at any point within three miles of the *Thames*, measured in a direct line therefrom, any sewer, drain, pipe, or channel with intent or in order thereby to provide for the flow or passage of sewage or of any matter aforesaid in such manner that the same will be carried, or be likely to be carried by, through, or out of that river, stream, cut, dock, canal, or watercourse into the *Thames:*

(4.) To cause or, without lawful excuse (the proof whereof shall lie on the person accused), to suffer any sewage or any matter aforesaid to flow or pass into any such river, stream, cut, dock, canal, or watercourse at any point within the distance aforesaid, down or through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose, in such manner that the same will be carried, or be likely to be carried by, through, or out of that river, stream, cut, dock, canal, or watercourse into the *Thames:*

If any person does any act or thing in contravention of this enactment, he shall for every such offence be liable on summary conviction to a penalty not exceeding one hundred pounds, and to a further penalty not exceeding fifty pounds for every day during which the offence is continued after the day on which the first penalty is incurred.

64. Whenever any sewage or any other offensive or injurious matter is caused or suffered to flow or pass into the *Thames*, or is caused or suffered to flow or pass into any river, or stream, cut dock, canal, or watercourse communicating with the *Thames*, at any point within three miles of the *Thames*, measured in a direct line therefrom, in such manner that the same is carried or is likely to be carried into the *Thames*, then and in every such case, whether any such sewage or other matter aforesaid had or had not been so caused or suffered to flow or pass before the passing of this Act, the Conservators, within a reasonable time after knowledge of the fact, shall and they are hereby required to give notice in writing under their common seal to the person or body causing or suffering the same so to flow or pass, to the effect that they require him or them to discontinue the flow or passage thereof as aforesaid within a time to be specified in the notice, not being in any case less than twelve months or more than three years; provided, &c.

THE FOURTH ACT, 1867.

The fourth Act (the Act recommended in the Act of 1866) extended the provisions of Section 52 and Sections 63 to 69, inclusive in the Act of 1866, "so as to apply to the *Thames* from the City Stone near *Staines* to the western boundary of the Metropolis, and to so much of every river, stream, cut, dock, canal, and watercourse communicating with that part of the *Thames* as lies withen three miles of the *Thames*, measured in a direct line therefrom."

It is entitled "An Act for Extending to the Thames between Staines and the Metropolis the provisions of the Thames Navigation Act, 1866, relating to the prevention of the pollution of the river, and for otherwise extending and amending the Thames Conservancy and Navigation Acts, and for other purposes." [17th *June*, 1867.]

Section 5 provides that it shall be the duty of the Conservators, by all lawful and proper means, to preserve and maintain at all times, as far as may be, the flow and purity of the water of the *Thames* and its tributaries down to the western boundaries of the Metropolis, and the discharge of that duty is defined as if the Acts of 1857, 1864, and 1866 were one Act.

Section 9 provides for an annual payment of £500 to the Commissioners of Her Majesty's Woods, Forests, and Land Revenues, in lieu of payments under Section 44 of the Act of 1857.

[It is this Act which gives the Conservators authority over police arrangements on any occasion when, for a boat-race or a launch, &c., large crowds may assemble.]

THE FIFTH ACT, 1870.

The fifth Act, amongst other things, provides for the extension of the authority of the Conservators from three to five miles on each side of the river.

It is entitled "An Act for Extending and Amending the Acts relating to the Navigation and Conservancy of the Thames, and for other purposes." [1st *August*, 1870.]

It is set forth in the preamble, "And whereas the limits within which the Conservators are authorised to exercise their powers of enforcing the discontinuance of the water of the Thames are too narrow, and it is expedient that they be extended, and that those powers be made to apply to the Thames below the Metropolis, except as in this Act provided . . . . Whereas it is expedient that measures shall be taken, as hereinafter provided, for the purpose of preventing obstructions to the navigation from the flow of the sewage into the river . . . . And whereas it is expedient that the Acts relating to the Conservators be in divers respects extended and amended . . . ." Three clauses only need be quoted.

7. "Section 64 of the Thames Act of 1866 shall have affect as if the words five miles therein inserted instead of the words three miles, and all provisions of that Act relative to that section, shall have affect accordingly."

18. The provisions of Section 52 and Sections 63 to 67, both inclusive, of the Thames Act of 1866, are hereby extended so as to apply to the Thames from the eastern boundary of the Metropolis to Yantlet Creek, and to so much of every river, stream, cut, dock, canal, and watercourse communicating with that part of the Thames as lies within three miles of the Thames, measured in a direct line therefrom, and for that purpose the term "this Act" used in those provisions shall be taken to

include the present Act, but nothing in this section contained shall in any wise prejudice, lessen, affect, or interfere with any of the rights, powers, authorities, or privileges of the Metropolitan Board of Works.

20. The Metropolitan Board of Works shall, at their own expense, keep the Thames free from such banks, or other obstructions to the navigation thereof, as may have arisen or may arise from the flow of sewage at their outfalls for the time being into the river, and for the purposes aforesaid the said Board shall have full power and authority from time to time to dredge the said river and to remove such banks or obstructions, but all such dredging operations shall be subject to the approval of the Conservators, and if they so require be carried on under their superintendence.

The possibility of the interests of the Metropolitan Board of Works and of the Thames Conservancy clashing was anticipated, and Clause 21 makes provision for the settlement of disputes between them; it provides that differences shall be referred to two arbitrators, one to be appointed by the Conservators and the other by the Metropolitan Board of Works, and an umpire to be appointed on the application of either party by the Board of Trade. And the clauses of the Railways' Clauses Consolidation Act, 1845, with respect to the settlement of disputes by arbitration, are to apply, so far as they can: And the arbitrators or umpires or referee are to make report to the Board of Trade: "And the Board of Trade may thereupon make such order and give such directions as to the removal of any such bank or other obstruction to the navigation of the river as they shall think fit, and if they shall be of opinion that any such bank or other obstruction shall have arisen partly from the flow of sewage from the said outfall works or either of them, and partly from other causes, they shall determine the proportion in which the expense of removing any such bank or obstruction shall be borne by the said Board of Works and the Conservators respectively, and the said Board of Works shall carry out, under the superintendence of the Conservators, all such orders and directions of the said Board of Trade, and the Conservators shall pay to the said Board of Works such proportion of any of the expenses incurred as shall be fixed by the Board of Trade, and in case of default, &c., &c."

THE SIXTH ACT, 1878.

The sixth Act gave increased extent of jurisdiction by repealing the seventh section of the Act of 1870, and making provision that Sections 63 and 64 of the Act of 1866 shall have effect as if the words ten miles were inserted instead of three miles.

It is entitled "An Act for conferring on the Conservators of the River Thames further Powers, and for Extending and Amending the Thames Acts, 1857 to 1870; and for other purposes." [8th *August*, 1878.]

The preamble sets forth that for sanitary reasons, and for the purpose of more effectually preventing the pollution and waste of the waters of the River Thames and its tributaries, and with the view of thereby improving the supply of water to the Metropolis and other places, it is expedient that the jurisdiction and powers in that behalf of the Conservators of the River Thames (in this Act called "the Conservators") be extended.

It then recites that the following six Companies supplying water within the Metropolis, by agreement with the Conservators, respectively make an annual payment for liberty to draw a certain quantity of water from the Thames:—

THE CHELSEA COMPANY.
THE LAMBETH COMPANY.
THE GRAND JUNCTION COMPANY.
THE SOUTHWARK COMPANY.
THE EAST LONDON COMPANY.
THE WEST MIDDLESEX COMPANY.

It then states that the funds available for the preservation of the navigation and the good government of the said river, and for the protection of the waters thereof between Staines and Cricklade (known as, and in this Act called, "the upper navigation"), are wholly inadequate for such purposes, and the six Companies are willing to make increased payments for the advantages already secured to them and to accrue to them under the provisions of this Act.

It is then enacted—

3. Section 7 of the Thames Navigation Act, 1870, is hereby repealed; and Sections 63 and 64 of the Thames Navigation Act, 1866, shall have effect as if the words ten miles were therein inserted instead of the words three miles; and all provisions of that Act relative to that Section shall have effect accordingly.

9. All persons cutting weeds, grass, or other vegetation in the River Thames, or in any stream, canal, or watercourse communicating with the river, shall remove therefrom such weeds, grass, or other vegetation immediately after cutting, so as to prevent their remaining in and decaying and contaminating the water of the said river, and no person shall throw, sweep, or cause to be thrown or swept, any weeds, grass, or matter of a like nature into the River Thames, or into any stream, canal, or watercourse communicating with the river; and if any person wilfully and with notice of this enactment does any act or thing in contravention of this enactment, he shall be liable to the same penalties as any person acting in contravention of Section 63 of the Thames Navigation Act, 1866, is liable.

THE PRESENT CONSTITUTION AND JURISDICTION OF THE BOARD.

The Board consists of 23 members, some of whom sit *ex-officio*, some as nominees of Government departments, and some as representatives of Corporations or trading communities, or of the old Conservators of the upper Thames.

The number is made up thus:—

		This column states under which Act the appointment is made.
	Ex-officio.	
1	The Lord Mayor	1st Act of 1857.
1	The Deputy-Master of the Trinity-house	1st Act of 1857.
	Representing Government Departments.	
1	One nominated by the Privy Council	1st Act of 1857.
2	Two ,, ,, Admiralty Commissioners	1st Act of 1857.
1	One ,, ,, Board of Trade	3rd Act of 1866.
	Representing Corporations.	
2 4	Two aldermen Four Common Councilmen } of the City of London	1st Act of 1857.
1	One representative of the Corporation of the Trinity-house	1st Act of 1857.
	Representing trading communities.	
2	Two by owners of shipping registered in the Custom-house books of the Port of London, called ship-owners	2nd Act of 1864.
1	One by owners of steamers surveyed and certificated as passenger steamers by the Board of Trade (under the Merchant Shipping Act, 1854, and Acts amending the same), and plying on the River Thames not seaward of Gravesend, called passenger steamers	
2	Two by owners of lighters and steam-tugs used on the River Thames	
1	One by owners of docks on the River Thames established under Charter or Act of Parliament and of legal quays and sufferance wharfs on the River Thames appointed by the Commissioners of Customs, called dock-owners and wharfingers	
	Representing the old "upper" Conservators.	
4	Four representing "Upper Navigation Commissioners"	3rd Act of 1866.
23		

The jurisdiction of the Conservators as regards the LENGTH of the river is now from Cricklade to an imaginary line drawn from the entrance to Yantlet Creek (Kent) to the City shore opposite Cauvey Island (Essex). It was at first

From Staines to this imaginary line by .... 1st Act of 1857.
The jurisdiction from Staines to Cricklade was added nine years after by.... 3rd Act of 1866.

The jurisdiction of the Conservators is, as regards the WIDTH of area, now for ten miles each side of the Thames, "measured in a direct line therefrom," so far as control over sewage pollution is concerned.

The jurisdiction was limited to the Thames itself by .... 1st Act of 1857.
It was extended to three miles on each side of the river for the purpose of the prevention of pollution by .... 4th Act of 1867.
It was extended to five miles by .... 5th Act of 1870.
,, ,, ten miles by .... 6th Act of 1878.

⁂ The Board has received from time to time additions to its power with respect to several of its functions, but as these notes are limited to control over pollution, they are not here referred to.

WHAT THE BOARD HAS ALREADY DONE IN CHECKING POLLUTION.

Section 64 of the Thames Navigation Act of 1866 directs the way in which the Conservators are to proceed in the prevention of pollution of the river, and the streams that flow into it.

Section 68:—"It shall not be competent for any person other than the Conservators, their officers, attorneys, solicitors, or agents, to institute or carry on any proceeding or prosecution under the provisions of this Act relative to the flow or passage of sewage, or of any matter aforesaid."

In the reports there are references to the appointment of officers for carrying out the work. For example:—No. 5. "Two additional men have been appointed as inspectors of nuisances." No. 10. "A superintendent of the upper part of the river has been appointed." "Lock-keepers and workmen are required continually to remove from the stream dead animals and other offensive or injurious matter into the river."

RETURN to an Order of the House of Commons, dated July 12, 1876, for a COPY "of STATEMENT of the result of the NOTICES served by the CONSERVATORS of the River THAMES under the Thames Conservancy Acts, for the discontinuance of the passing of sewage, or any other offensive or injurious matter, into the river above the intake of the water companies supplying the metropolis." The return is signed by the Secretary of, and dated from, the Local Government Board. The statement is signed by the Secretary to the Thames Conservancy. The return is published in "Accounts and Papers," 1876, Vol. LX, p. 641. The following is an abstract only. The date given in each case is that when the diversion of the sewage was completed:—

Oxford	Works in progress.	Cookham	Oct., 1871.
Abingdon	Borough works in progress.	Cliefden	Oct., 1871.
Christ's Hospital	Oct., 1870.	Maidenhead	April, 1871.
Mr. Yeates..	March, 1873.	Windsor	Works in progress.
,, Bailey..	Feb., 1874.	Windsor Castle	, 1872.
Twelve other notices	No information.	Windsor (Old)	Sep., 1871.
Wallingford—		Eton College	No information.
Borough	May, 1874.	Eton Union	May, 1874.
Mr. Hilliard	Oct., 1871.	Slough	May, 1874.
Eight other notices	No information.	Datchet	May, 1874.
Goring	Oct., 1871.	Clewer—	
Pangbourne	June, 1876.	Sir D. Gooch	Nov., 1873.
Maple Durham	Oct., 1871.	Mr. Gristwood	June, 1874.
Reading	Works in progress.	Egham	June, 1874.
Shiplake	Oct., 1871.	Staines—	
Wargrave.	Oct., 1871.	2 notices	April, 1875.
Henley-on-Thames—		4 others	Under notice by Solicitor.
Mayor and Aldermen	Oct., 1871.	Chertsey	April, 1875.
Inspectors of Nuisances.	Aug., 1869.	Shepperton	April, 1875.
Remennam	Oct., 1871.	Weybridge	April, 1875.
Hurley	June, 1874.	Halliford	April, 1875.
Bisham	Oct., 1871.	Walton-on-Thames	March, 1874.
Great Marlow	Oct., 1871.	Sunbury	March, 1874.

⁂ Since the compilation of this report in 1876 the following works have been completed:—

Abingdon.............................. December, 1877.
Reading .... December, 1877.
Windsor .... October, 1877.

EXTRACTS FROM ANNUAL REPORTS OF THE PROCEEDINGS OF THE CONSERVATORS OF THE RIVER THAMES.

THE REPORTS ARE MADE IN CONFORMITY WITH SECTION 48 OF THE THAMES CONSERVANCY ACT OF 1857.

	Parliamentary Papers.	
Rep. Con. Th. 1.	1859. Sess. 2. xxvi. p. 369.	[The First Report includes from October 7, 1857, to 31 December, 1858.] Mentions first meeting of the Conservators held at Mansion-house, London, on October 7, 1857. Election of engineer (Mr. S. W. Leach), and secretary (Commander E. Burstal, R.N.), October 10. The Corporation of London transferred to the Conservators the land and other property the Corporation had acquired for the maintenance and improvement of the River Thames. The meetings were held at Mansion-house till November 25, when the house in Trinity-square, Tower-hill, was purchased. Record of work done refers to dredging, removing shoals, the raising of wrecks, and general regard to navigation. Teddington Lock reconstructed. "The state of the river in hot weather, in the months of June and July last, have been carefully considered with a view to ascertaining the cause."
2. For 1859.	1860. lxi. p. 551.	[This and succeeding reports are for the twelve months from January 1 to December 31 in each year.] Moulsey Weir reconstructed. Record of shoals moved and wrecks raised.
3. For 1860.	1861. l. p. 765.	Attention paid to banks and sea walls. Shallows removed and river deepened. The Commissioners find out they have not power over fisheries.—*(A Queen's Bench decision.)*
4. For 1861.	1862. xlvii. p. 502.	Allusions are mostly to piers and quays. "Every effort has been made to improve the condition of the water of the river. The discharge of poisonous matter from gas and other works they believe has been considerably checked by the vigilance of their officers and the prosecutions they have felt it their duty to institute against persons offending."
5. For 1862.	1863. l. p. 127.	Mostly on dredging and moorings. "A rigid inspection has been maintained, and such proceedings as appear necessary have been taken to check, as far as possible, the practice of discharging mud and other deleterious matter into the river, and for this purpose two additional men have been appointed as inspectors of nuisances."
6. For 1863.	1864. l. p. 175.	On dredgings, and piers, and moorings.
7. For 1864.	1865. xlvii. p 179.	Report complains that Thames Embankment has lessened the volume of water without adding compensation by dredging. Six additional members added pursuant to 27 and 28 Vic., c. 113. Attempt to stop Kingston-on-Thames sewage scheme failed.
8. For 1865.	1866. lix. p. 189.	(The Report is only 12 lines.) Mentions the Conservators' power over "the prevention of nuisances, or of the pollution of the stream by the discharge of noxious matters into the river or its affluents."
9. For 1866.	1867. lix. p. 173.	"Proceedings have been instituted against persons for throwing mud into the river, and against the owners of gas and chemical works for permitting gas refuse and offensive matter to pass into the river, and 77 convictions have been obtained." . . . . . . "By the 52nd section of the Act of 1866, the duty of scavenging the river was imposed upon the conservators, and this has been carefully attended to." . . . . . . "Early in the present year, and as soon as the Conservators had obtained the necessary information, they caused notices to be served on the proper authorities at Oxford, Abingdon, Wallingford, Reading, Henley, Marlow, Cookham, Windsor, and Eton, requiring them to discontinue the flow or passage of sewage or any other offensive or injurious matter into the river. . . . ." Four Conservators added.
10. For 1867.	1867-8. lv. p. 635.	Reference to dredging, &c. "In conformity with the requirements of the Thames Conservancy Act passed in June, 1867, notices have been served on all persons or bodies in charge of sewers between Staines and the western boundary of the metropolis, requiring them to discontinue the passing of sewage into the river, and there appears to be a general desire on the part of those authorities to meet the requirements of the legislature." * * * * * * * "Throughout the course of the river the scavenging imposed by the Act of 1866 has been attended to. The lock-keepers and workmen are required continually to remove from the stream dead animals and any other offensive substances that may be floating upon it." "A superintendent of the upper part of the river has been appointed, whose

		special attention is directed to the storage and purity of the water. In addition to the notices reported last year that were served upon the local authorities having charge of the drainage, the Conservators have, in conformity with the 64th section of the 29 and 30 Vic., c. 89, given notice to the owners of every paper mill, on and within three miles of the river, requiring them to discontinue the practise of passing the liquid matter produced in the manufacture of paper into the river."
11. For 1868.	1868-9. l. p. 637.	Reference generally to efficiency of works. "The condition of the river near the main drainage outfalls at Barking and Crossness has continued to receive their anxious attention. Repeated surveys having convinced them that shoals have been created by the deposit from these outfalls, the Conservators made a formal complaint to the Secretary of State for the Home Department, as directed by the Act of Parliament 21 and 22 Vic., c. 104; and although no further decrease of the depth of water or actual impediment to navigation has yet been caused, the Conservators find that the deposited matter now spreads over an increasingly extensive area of the bed of the river, and this fact must be regarded with considerable apprehension as to the results. "The Conservators feel it their duty to remark that a considerable portion of the sewage of the metropolis north of the Thames still continues to pass into the river between Chelsea and the Isle of Dogs. * * * * * * * "The Conservators have not omitted any opportunity for improving the condition of the water. They have given the requisite notices to discontinue passing sewage and refuse into the river. In many cases the discharge has been stopped, and in many others non-compliance has arisen from the uncertainty as to the best mode of disposing of the sewage. In nearly every case the local authorities and others have now decided to adopt some practical scheme, so that in a short time the Conservators hope they may be able to announce that sewage and other impurities no longer pass into the river westward of the metropolis."
12. For 1869.	1870. lvi. p. 729.	"In consideration of the difficulties experienced by several large towns in disposing of their sewage, the Conservators have, on various occasions, extended the time allowed for this purpose."
13. For 1870.	1871. lvi. p. 801.	Teddington Weir rebuilt. "With reference to the condition of the water they have unceasingly endeavoured to prevent the introduction of sewage and other impurities into the river, and have caused the river above the metropolis to be carefully scavenged. "In manycases their notices and remonstances have had a beneficial effect. Eton has set an excellent example in having diverted its sewage; and the large and important town of Reading obtained parliamentary powers in the last session effectually to divert its sewage from the Thames, and the local board has taken vigorous measures to carry the Act into execution. "Plans for the complete drainage of Oxford, and the diversion of the sewage from the river have been adopted by the local Board, and approved by the Government. Windsor and Kingston-on-Thames, both of which have received final notices to discontinue the discharge of their sewage into the Thames, have as yet executed no works."
14. For 1871.	1872. xlvii. p. 747.	Has reference mainly to locks. Complaint of want of funds.
15. For 1872.	1873. liii. p. 649.	All has been done "to the furthest extent which the funds at the disposal of the Conservators would admit."
16. For 1873.	1874. lii. p. 739.	The Conservators have not ceased to urge upon those local authorities who have not yet complied with the notices served on them, requiring the diversion from the river of the sewage of the districts respectively under their control.
17. For 1874.	1875. lx. p. 713.	Report begins with drawing attention to fact that the river under the jurisdiction of Conservators is divided into lower navigation and upper navigation. LOWER NAVIGATION (Staines to Yantlet). The Conservators continue to watch with anxious apprehension the discharge of the sewage of the metropolis at Barking Creek and Crossness; the periodical surveys made by their officers show that at the latter place, especially the shoal near the outfall, is gradually increasing and extending. A letter, accompanied by plans, was sent to the Metropolitan Board of Works in July, 1874, directing attention to this subject. UPPER NAVIGATION (Staines to Cricklade). Want of funds again noticed. On reviewing the results of the notices served on various persons and places, requiring the diversion of sewage or other offensive or injurious matter from flowing into the river, the Conservators are able to report that above the intakes of the water companies only four towns shall pass their sewage into the river: of

		these, two, Oxford and Reading, have sewage works in a forward state; and of the other two, Windsor have commenced the sewage works, and Abingdon is about to do the same; a hope may, therefore, be entertained that above the source of the chief water supply of the metropolis all sewage will very soon be diverted from the river. Between the intakes of the water companies and the western limits of the metropolis, where the main drainage schemes comes into operation, a less satisfactory state of matters prevail. Notwithstanding the measures taken by the Conservators under their Acts of Parliament, the local authorities, with the exception of Twickenham, have not yet diverted their sewage from the river. The Conservators will not relax their efforts to enforce a compliance with the provision of the Thames Conservancy Acts till the diversion of the sewage and the consequent purification of the river above the limits of the metropolis has been fully accomplished.
18. For 1875.	1876. lx. p. 635.	Dredging between Teddington and Richmond has been continued. * * * * The annual survey made by the officers of the Conservators at the Barking and Crossness sewage outfalls in the months of May and June, 1875, shows an increase of the mud deposit from the discharge of the sewage of the metropolis at these points. * * * * * * * On the subject of the diversion of the sewage from the river, a statement showing what has been done up to the present time above the intake of the water companies has been recently laid before Parliament; it is, therefore, unnecessary to refer in detail to this part of the sewage question, especially as the present report only deals with the occurrences of the year ending 31st December. In the district below the intakes of the water companies, but above the western limits of the metropolis, the sewage of the various places, with the exception of Twickenham, has not yet been diverted from the river. In the latter part of 1875, an inquiry was instituted by Colonel Cox, R.E., under the direction of the Local Government Board, and at the instance of the local authorities, as to the best mode of dealing with the sewage of the various places in the Thames valley below the intakes.
19. For 1876.	1877. lxviii. p. 537.	A careful survey of the state of the river near the sewage outfalls at Barking and Crossness is made annually. The survey of 1876 shows that the deposit still continues, notwithstanding the great scouring effects of the floods in the winter 1875-6. * * * * * * * Notwithstanding delays caused by the recent floods, the Conservators hope that all the sewage above the intakes of the metropolitan water companies will soon be diverted from the river. In the district below the intakes of the water companies, and above the western limits of the Metropolis, the sewage of various places has not yet been diverted from the river, notwithstanding the legal measures taken by the Conservators. Two reports have been made to the Local Government Board by their inspector, as to uniting the various authorities of this locality, so as to form one board dealing with the sewage of the combined district. As the Bill for carrying out this mode of dealing with the sewage is now before Parliament, the Conservators hope that this sewage will ere long cease to flow into the river.
	p. 543.	⁂ *This report is followed by one on the works in the upper district of the river, and on the floods in the Thames valley.*
20. For 1877.	1878. lxi.	The annual surveys of the river near the great sewage outfalls at Barking and Crossness having shown that accretions are taking place in the river, both above and below these outlets, the Conservators deemed it desirable that the facts brought to light by these annual surveys, and by the analyses of materials taken from this part of the river, should be thoroughly investigated. This inquiry was entrusted to Captain Calver, R.N., F.R.S. . . . On the receipt of his report it was sent to the Metropolitan Board of Works, from whom the Conservators have recently received a reply, which is now under their consideration. * * * * * * * Owing to the high floods early in the year, the sewage works at Oxford have been delayed, but the Conservators trust that ere long these will be completed. Owing to an unforseen difficulty, the Windsor sewage works are not quite, though very nearly, completed. WITH THESE EXCEPTIONS, ALL THE SEWAGE FORMERLY FLOWING INTO THE RIVER ABOVE THE INTAKES OF THE WATER COMPANIES HAS, SO FAR AS THE CONSERVATORS HAVE BEEN ABLE TO DISCOVER, NOW BEEN DIVERTED FROM THE RIVER. Careful supervision has been exercised over the mills, which are chiefly situated in the tributaries within the five mile limit of the Conservators' jurisdiction, and effluents of an obnoxious and injurious character have been prevented from flowing into the river.

ACTS OF PARLIAMENT.

		Date.	Short Title.
1	Vict. 20 and 21, cap. cxlvii. (Local.)	17th Aug., 1857.	The Thames Conservancy Act, 1857. [Given in sec. clxxx.] [The preamble recites all previous Acts.]
2	Vict. 27 and 28, cap. cxiii. (Gen. pub.)	29th July, 1864.	The Thames Conservancy Act, 1864. [Given in sec. i.]
3	Vict. 29 and 30, cap. lxxxix. (Gen. pub.)	6th Aug., 1866.	The Thames Navigation Act, 1866. [Given in sec. i.]
4	Vict. 30, cap. ci. (Local.)	17th June, 1867.	The Thames Conservancy Act, 1867. [Given in sec. 1.]
5	Vict. 33 and 34, chap. cxlix. (Local.)	1st Aug., 1870.	The Thames Navigation Act, 1870. [Given in sec. i, which also provides that "This Act and the Thames Acts (exclusive of the Thames Act of 1810) may be cited together as 'The Thames Acts 1857 to 1870.'"
6	Vict. 41 and 42, chap. ccxvi. (Local.)	8th Aug., 1878.	The Thames Conservancy Act, 1878. [Given in sec. i, which also provides:—"This Act and the Thames Acts, 1857 to 1870, may be cited together as the Thames Acts 1857 to 1878, and shall be read and have effect together as one Act."

⁂ The titles "Navigation Act," or "Conservancy Act," do not indicate in any way which Acts contain provision for the prevention of pollution. These are Acts 3, 5, and 6.

REPORTS ON STATE OF THAMES.

Rep. Sel. Com.	1836. Vol. xiv.	Report of Select Committee on the state of the Port of London. Report. Minutes of Evidence. Appendices.
Rep. Sel. Com.	1840. Vol. xii. p. 271.	Report of Select Committee on Thames Embankment. Report, Evidence, Appendices. Appendix 2 contains, at p. 86, sectional area of Thames taken in 1823 and 1831.
	1857. Vol. xiii. p. 165.	Report made to the First Commissioner of Works, by Commander Burstal, R.N., on the state of the River Thames from Putney to Rotherhithe, dated the 27th day of January, 1857. Report, 4 pages; sections, 13 sheets.
	1865. Vol. xlvii. p. 175.	Report by Mr. S. W. Leach, engineer to the Conservators of the River Thames, upon the present condition of the works in the upper districts of that river.
	1867-8. Vol. lv. p. 611.	Correspondence between the Thames Conservancy Board and the Metropolitan Board of Works on formation of mud.

617 Notices given.

SELECT COMMITTEES.

Sel. Com. on Thames Conserv.	1863. xii.	Report of the Select Committee appointed to inquire into the operation of the several Acts of Parliament relating to the Conservancy of the River Thames, to the buoyage, &c., &c. Report, x pages. Minutes of Evidence, pp. 274. Appendix 2 (p. 302) gives outline of law, with references. p. 313 gives other rivers.
	1877. xvii.	Select Committee Thames Flood Prevention.

COMMISSIONS.

	1854. xxvi.	Commission on Corporation of London. p. 26 of Report on Conservancy. See also Index. E. L. Pemberton gives explanation of case between Board of Works and Corporation. It began in 1836..
		Royal Commission to inquire into the Municipal Corporations of England and Wales. 2nd Report, London and Southwark (ordered to be printed 25th April, 1837.] No. 239.

LIST OF BOOKS AND PAMPHLETS.

Author.	Date.	Title.	Publisher.
Roger Griffiths	1746	An Essay to prove that the Jurisdiction and Conservacy of the River Thames is committed to the Lord Mayor and City of London, both in point of right und usage	Robert Brown.
Robert Binnell	1758	A Description of the River Thames	T. Longman.
Alexander Pulling	1842	A Practical Treatise on the Laws, Customs, and Regulations of the City and Port of London	V. and R. Stevens and G. S. Norton.
George Norton	1869	Commentaries on the City of London. (Conservacy, p. 390, &c.)	Longmans, Green, & Co.
Joseph F. B. Firth	1876	Municipal London. (Conservancy, p. 465, &c.)	Longmans, Green, & Co.
E. K. Calver	1877 Oct. 15	Report upon the Discharge of Metropolitan Sewage into the River Thames at Barking Creek and Crossness	E. F. Gooch & Son.
S. W. Leach	1878 Aug. 31	Remarks on the Report of Bazalgette, Law, and Chatterton	Printed by E. F. Gooch & Son.
E. Burstal	1878 Sept. 5	Observations on the Reply of Bazalgette, Law, and Chatterton	E. F. Gooch & Son.
E. K. Calver	1878 Sept. 6	A Rejoinder to Bazalgette, Law, and Chatterton, &c.	E. F. Gooch & Son.

CATALOGUE

OF THE

EXHIBITION OF MECHANICAL & CHEMICAL APPARATUS,

RELATING TO

WATER SUPPLY, TREATMENT OF SEWAGE AND HEALTH.

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1. **Ahrbecker, H. C., and Son, 117, Stamford-street, S.E.—Patent water meter.**
2. **Alley and MacLellen, 2, Peel-street, London-road, Glasgow.—Foulis' patent water governor and "The Sentinel" water meter. (See advertisement.)**
3. **Banner, E. G., 11, Billiter-square, London, E.C.—Patent ventilating cowls, traps, and drain-pipes. Models illustrating Banner's system of sanitation. (See advertisement.)**
4. **Beard, Dent, and Hellyer, 21, Newcastle-street, Strand, W.C.**
    - (1.) Patent drain syphon and sewer interceptor.
    - (2.) Patent vortex closet.
    - (3.) Patent waste preventor and drain interceptor.
    - (4.) Hellyer's patent triple-dip trap or waste receiver and drain interceptor.
5. **Bel, A. and Co., 34, Maiden-lane, W.C.—Apparatus for ascertaining the hardness of, and for purifying water by Clarke's process. (See advertisement.)**
6. **Bird, P. Hinckes, F.R.C.S., F.L.S., 1, Norfolk-square, W.—Models illustrating a system of costless ventilation.**
7. **Bolding, John, and Sons, 19, South Molton-street, W.—Improved water-closets.**
8. **Bostel, D. T., Duke-street, Brighton.—Patent Excelsior valveless water-closet and automatic self-flushing cistern. (See advertisement.)**
9. **Boyle and Co., 100, Mitchell-street, Glasgow.—Patent self-acting air-pump ventilators. (See advertisement.)**
10. **Bradbury, William, 57, Cross-street, Oldham, Lancashire.—Patent non-infectious, non-repulsive, portable, and sanitary bed-commode and warming-pan combined.**
11. **Brough and Bell, 5, Chester-road, Sunderland.—Patent self-closing taps and valves.**
12. **Buck, N., 31, Brondesbury-villas, Kilburn, N.W.—Drawings and working model, illustrating Buck's rain water percolator, or self-acting apparatus for storing rain water.**
13. **Capper and Co., 69, Gracechurch-street, London, E.C.—Pearson's patent trapless "Twin Basin" water-closet.**
14. **Carsley, W. and S.—Models illustrating Jewell's patent improved system of drainage and ventilation, for preventing foul gas from entering house drains and thoroughly ventilating each room**
15. **Casartelli, Joseph, 43, Market-street, Manchester.—Stand for disinfecting rooms by sulphurous acid gas, as used in the Oldham Health Department.**
16. **Clarke, J. F., 49, Moorgate-street, E.C.**
    - (1.) Patent portable hydrant.
    - (2.) Patent self-flushing water-closet cisterns
    - (3.) Dr. Letheby's improved sanitary filter.
    - (4.) Patent range tap for supplying cold water to the boiler at the same time that hot water is being drawn off.
    - (5.) Drawings of self-flushing, water waste preventing water-closet, and Clarke's patent snow-melting apparatus.
    - (See advertisement.)
17. **Craig, J. and M., Hillhead, Kilmarnock.**
    - (1.) Buchan's patent ventilating syphon traps and fittings for drains, soil pipes, &c.
    - (2.) Buchan's patent flat and raised cleansing or ventilating stones.
    - (3.) Buchan's anti bell-trap.
    - (4.) Buchan's patent self-acting induced current fixed ventilator.
    - (See advertisement.)
18. **Crossley, D., Brighouse, Yorkshire.—Crossley's improved patent ventilators.**
    - (1.) Self-acting valve ventilator.
    - (2.) Self-acting screen ventilator.
    - (3.) Fixed louvre ventilator.

19. Davis and Co., 90, Crampton-street, Newington-butts, London, S.E.—A B C water testing apparatus.

20. Denton, J. Bailey, 22, Whitehall-place, S.W.—Self-supplying aërated filter.

21. Goodwin, R., Chesterfield.—"Perfect" stench and vermin proof trap, with mud box, and arrangements for keeping drains free from rubbish; also loose slide to admit of the whole being thoroughly cleansed when required.

22. Greenway, H., Plymouth.—Model of transverse section of a one-story building, showing method of improved hospital construction as suitable for a fever hospital.

23. Griffin, John J. and Sons, 22, Garrick-street, W.C.
    (1.) Dr. Clarke's apparatus and solutions for testing the hardness of waters, and for softening them.
    (2.) Wanklyn's apparatus for testing waters by the ammonia process.
    (3.) Apparatus for working the moist combustion process, as patented by Wanklyn and Cooper.
    (See advertisement.)

4. Haresceugh, B. B., and Co., Bentinck-street, Sunny-bank, Leeds.—Oak excreta receptacle with patent spring lid.

25. Heron, Dr., 40, Margaret-street, Cavendish-square, W.—Model of plan for preventing the entrance of sewer-gas into dwellings.

26. Horseley Company, Limited, Horseley Works, Tipton, Staffs.—Latham's 20-in. sewer ventilator.

27. Howard, E., 1A, Upper Baker-street, W.—Closet, with improved patent duplex lid fittings and automatic flusher and ventilating flue. (See advertisement.)

28. India-rubber, Gutta-percha, and Telegraph Works Company, Silvertown, Essex, and 106, Cannon-street, E.C.—Electrical water-level indicator, for showing the actual height of the water-level in feet or inches, in reservoirs, tanks, rivers, tideways, &c., at no matter what distance from the water the instrument may be placed. (See advertisement.)

29. Johnson, —, Engineering Works, Carpenter's-road, Stratford, E.—Patent hydraulic filter for the treatment of sewage sludge on the pneumatic system. (See advertisement.)

30. Lambert, Thomas and Sons, Short-street, Lambeth, S.E.—Patent self-closing valves and water-waste preventors.

31. Le Grand and Sutcliff, Magdala Works, 100, Bunhill-row, E.C.—Model of Norton's patent Abyssinian tube well driving apparatus.

32. Lloyd, T., The Square, Winchester, Hants.—Patent extract ventilating cowls.
    (1.) In strong zinc for 2-inch ventilating shaft from soil-pipe.
    (2.) In copper for zinc shaft from drain.
    (3.) Model in strong zinc with base and shaft for ventilation of buildings.
    (4.) For ventilation of railway carriages or closed vehicles. (See advertisement.)

33. London and General Water Purifying Company, 157, Strand, London, W.C.—Various forms of filters: water-testing apparatus.

34. Monson, E., High-street, Acton, W.—Models of bricks made from sewage sludge.

35. Moule's Patent Earth-closet Company, 5A., Garrick-street, London, W.C.—Moule's patent pull-up action apparatus for earth or ashes, and the hopper only, of a similar apparatus, showing the parts for delivering the earth. (See advertisement.)

36. Muller, J., 30, Craven-street, Strand, London, W.C.—Patent water meter.

37. Oakes and Robinson, 39, Queen Victoria-street, London, E.C.—Model of patent filter press, for rapidly and economically extracting moisture from the semi-fluid products of breweries, sewage precipitation works, potteries, sugar factories, chemical works, &c. (See advertisement.)

38.—Ormsby, R., Scientific Club, 7, Savil-row, W.—Model of artificial collecting-ground for rain water.

39. Pain, E. J., 19, Buckingham-street, Strand, W.C.—Model of Danchell's patent filter press, for filtering all fluids and semi-fluids, with sample of water and varnish before and after filtration. (See advertisement.)

40. Phillips, H., Heavitree, near Exeter.—Patent dry closet.

41. Phillips, W., 160, Young-street, Sheffield.—Patent sanitary closet.

42. Pritchett, G.E., Bishop Stortford, Herts.
    (1.) Example of Pritchett's patent hollow flooring for damp situations and for receiving cement, tile, and asphalte floors.
    (2.) Do. do. for lining walls to prevent passage of damp and to promote ventilation.
    (3.) Do. do. for ventilation.

43. Sanitary Appliances Company, Factory-lane, Salford, Manchester.—Models of Morrell's patent cinder-sifting ash closets.

44. Sanitas Company, Letchford-buildings, Three Colt-lane, Bethnal-green, E.—Sample of "Sanitas" fluid and powder. Specimens of meat and fish preserved in sanitas. (See advertisement.)

45. Scott's Sewage Company, Royal Albert-hall, Kensington, W.
    (1.) Illustrations of manufacture of Portland cement from sewage water from Burnley, and of ammonic Fimus Manure from Birmingham excreta made by General Scott's patent processes.
    (2.) Photographs and plan of the Burnley Sewage Works.

46. Silicated Carbon Filter Company, Church-road, Battersea, London, S.W.—Silicated carbon filters in various forms.

47. Sinclair, James, 104, Leadenhall-street, E.C.
    (1.) Gardner's patent household rapid water filter.
    (2.) Berlon, Furstenhagen and Wildts "Indispensable" patent double acting filter.

48. Stevens, C. R., Lee-green, S.E.
    (1.) Patent self-acting exhaust ventilator.
    (2.) Drawer or inlet wall ventilator, for creating a vertical current of air.
    (3.) Exhaust cowl for smoky chimnies.

49. Stiff and Sons, High-street, Lambeth, S.E.—Stiff's "Interceptor" trap, Weaver's trap, Bavin trap. Garrett trap, Eureka trap, and sections of same, Soper's hospital drain, and portable disinfector. (See advertisement.)

50. Taylor, E. S. and Co., 9 and 10, Sheffield-buildings, Victoria-street, Liverpool, and 63, Queen Victoria-street, E.C.—"Empress" water motor.

51. W. Tonks and Sons, Moseley-street, Birmingham.
    (*a*.) Model, showing the action of two automatic fasteners fixed in the upper sash, and the action of the releaser fixed on the lower sash; for "ventilation with security" when the window is open at top, bottom, or middle.
    (*b*.) Model, showing the action of two automatic fasteners fixed in the upper sash, as in model *a*; but with the advantage of opening and closing the upper sash, on pulling the cord attached to the upper sash for that purpose.
    (*c*.) Model, Currall's patent inlet ventilator fixed over an aperture in a rail of a door; ensuring plenty of ventilation without any draught being felt, the incoming current of air being turned upwards in a direct line towards the upper part of the room, where it gradually diffuses.
    (*d*.) Model, Currall's patent inlet ventilator fixed on the bottom rail of the lower sash; for ventilation without draught.
    (*e*.) Model, Currall's patent inlet ventilator fixed on the lower sash; for ventilation without draught when the lower sash is raised a little. (See advertisement.)

52. Warner, J. and Sons, The Crescent Foundry, Cripplegate, E.C.
    (1.) Warner's patent valve closet, with improved basins and Bower's patent overflow sewer-gas trap combined with patent supply valve and copper case pneumatic regulator.
    (2.) The Bower patent sewer-gas trap.
    (3.) Various forms of valves for baths, &c. (See advertisement.)

53. White, W. T., 332, Kennington-road, S.E.—Samples of "Euchlorine" disinfectant.

INDEX.

" Abyssinian tube wells" (Sutcliff), 113
Adams, Mr., *disc.*, 177
Alcock, Mr., *disc.*, 169, 175, 182, 183
Ansted, Prof. D. T., sugggestions for dividing England and Wales into water-shed districts, 43
——————— " River conservancy," 94
Ash-closets, cinder sifting, (Morrell), 150
Atchison, A. T., suggestions for dividing England and Wales into water-shed districts, 27

Bann (Upper) River, on the water supply of the, and the amount of rainfall utilised (J. Smyth, jun.), 107
Banner, E. G., " House drainage." The Banner system of house sanitation, 147, 182, 183
Bedford, inquiry as to works of sanitation at, (Chadwick), 133
Birkett, Mr., *disc.*, 173, 177, 189, 183
Bright, Mr., of Leamington, *disc.*, 160
Brown, A. H., M.P., " The incidence of rating for sanitary purposes in rural districts," 72, 161
——————— *disc.*, 163; *resolution*, 168
Brown, John, "Remarks on some of the diseases due to sewer-gas poisoning," 116

Catalogue of exhibition, 206
Caterham, the recent outbreak of enteric fever at, (Thorne), 117, 172
Chadwick, Edwin, "Course of inquiry as to works of sanitation, and as to their expense and results," 130, 181
————, *disc.*, 161, 163, 164, 165, 167, 176, 171, 181, 182
Churchill, Lord Alfred S. (Chairman, 1st morning), 158, *resolution*, 171
Cinder-sifting ash-closets (Morrell), 150.
Clutterbuck, Rev. James C., "The water supply of large towns," 84
Cole, Granville, Ph.D., " Some experiences of sewage effluents, and burning sludge into cement," 137
Cole, Sir Henry, K.C.B., "Notes of progress with sewage since the first Congress of the Society of Arts in 1876, submitted to the fourth Congress in 1879," 123, 178
—— *disc.*, 181
Colebrook, Mr., *disc.*, 173, 177, 182
Conder, Francis B., C.E., "On the utilisation of the water supply of England," 74
Cresswell, C. N., " The Thames and its tributaries," 127, 178
——————, *disc.*, 162, 169, 170, 173, 177, 180, 182
Crewe sewage farm, 187
Croydon, inquiry as to works of sanitation at, (Chadwick), 131
————, works of sewage and sewage disposal—Croydon sanitary authority (Latham), 136
Cutler, W. H., *disc.*, 164

Denison, Archdeacon G. A., supply and storage of pure drinking water, East Brent, Somerset, 97
Denton, J. Bailey, "National water supply," 110; " Domestic filtration of water conserved in tanks and cisterns," 110
De Rance, C. E., "Pervious rocks of England and Wales," 85
Dillon, James, "On the effects of under and arterial drainage on rivers and floods," 97, 166
Diseases due to sewer-gas poisoning, remarks on some of the, (Brown), 116
Drainage, on the effects of under and arterial, on rivers and floods (Dillon), 97, 166

East Brent, Somerset, supply and storage of pure drinking water (Denison), 97
Edmonton sewage farm, 187
Eldred, Mr., *disc.*, 170
Enteric fever at Caterham, the recent outbreak of (Thorne), 117, 172
Epidemics produced by polluted water supply (Hart), 119, 173
Essays on water supply, 1-71
Evans, John, *disc.*, 158, 161

Field, Rogers, *disc.*, 171
Filtration, domestic, of water conserved in tanks and cisterns (Denton), 110
Foote, G., "The water supply of Kington and neighbourhood," 111

Galton, Capt. Douglas, *disc.*, 161, 173, 179, 182; *resolution*, 171
Goslin, S. B., suggestions for dividing England and Wales into water-shed districts, 65
Grindle, Mr., *disc.*, 181

Hamilton, Mr. (Mayor of Oldham), *disc.*, 176
Hart, Ernest, " Epidemics produced by polluted water supply," 119, 173
——————, *resolution*, 176; *disc.*, 177
Hawkshaw, J. Clark, " River conservancy, illustrated by drainage administration in Holland," 101, 172
Hewson, Mr., *disc.*, 183
Holland, river conservancy, illustrated by drainage administration in, (J. C. Hawkshaw), 101, 172
Homersham, Mr., *disc.*, 167, 168
House drainage, the double check system (Masters), 144
———————, the Banner system of house sanitation, 147
Hillé, F., "Ten years' practical experience in sewage treatment," 139
Hull, Professor Edward, " On the underground water supply of villages, hamlets, and country parishes, of the Central and Eastern Counties of England," 36

Jones, Lieut.-Col. Alfred S., "Sewage disposal at Wrexham," 141, 182

Kington, water supply of, and neighbourhood (Foote), 111

Latham, Baldwin, "Works of sewage and sewage disposal—Croydon sanitary authority," 136
——————— *disc.* 168, 169, 171, 172, 174, 181
Lemon, James, *disc.*, 171, 182
Lloyd, Mr., *disc.*, 166, 169
Longdin, Mr., *disc.*, 183
Lucas, Joseph, suggestions for dividing England and Wales into water-shed districts, 16
—————— "Watershed lines; subterranean water-ridges," 91, 165
—————— *disc.*, 158, 173
Lynam, James, C.E., " The sanitary state of the River Shannon referred to bad regulated weirs," 105

Mackinnon, Mr., *disc.* 175
Malvern Link sewage farm, 187

Masters, Henry, "The double check system of house drainage," 144, 182
————— *disc.*, 172
Maxwell, Mr., *disc.*, 175
Morrell, Conyers, "Cinder-sifting ash-closets," 150

North, S. W., *disc.*, 171, 176, 183, 184
Norwich sewage farm, 187
"Notes on previous inquiries" on water supply; supplement, 189
Nottingham, on the substitution of the pail system for the privy and midden system in, (Seaton), 155

Oldham (Mayor of), *disc.*, 174
Olrick, Lewis, *disc.*, 174

Pail system, on the substitution of the, for the privy and midden system in Nottingham (Seaton), 155
Paris, sewage irrigation in, (Sturge), 151
Penning, W. H., suggestions for dividing England and Wales into water-shed districts, 35
Pervious rocks of England and Wales (De Rance), 85
Prestwich, Prof. Joseph, "National water supply," 93

Ramsay, Prof., *disc.*, 159
Rating, incidence of, for sanitary purposes in burial districts (A. H. Brown), 72, 161
Rawlinson, Mr., *disc.*, 166, 167, 178
Reigate sewage farms, 187
Resolutions;—
  On the appointment of a Royal commission, 171
  Mr. Brown's on incidence of rating, 168; withdrawn, 171
  Mr. E. Hart's on the poisoning of water by evacuations of patients suffering from enteric fever, 176
  Mr. Cresswell's on the purifying of the Thames from sewage 178; altered, 180
  Passed in 1876 and 1877, 184
River conservancy (Ansted), 94
————, illustrated by drainage administration in Holland (J. C. Hawkshaw), 101, 172
Rugby sewage farms, 188

Sanitation, course of inquiry as to works of, and as to their expense and results (Chadwick), 130
Schofield, Mr., *disc.*, 184
Sconiton and Pendlebury sewage farm, 188
Seaton, Edward, M.D., "On the substitution of the pail system for the privy midden system in Nottingham, and its effects in reducing the mortality and sickness from enteric and continued fevers," 155, 183
————— *disc.*, 173, 174, 182, 183
Sewage, methods of, *papers*, 123—157
———, notes of progress with, since the first Congress of the Society of Arts in 1876, submitted to the fourth Congress in 1879 (Sir H. Cole), 123
Sewage disposal, works of sewage and,—Croydon sanitary authority (Latham), 136
————— at Wrexham (Jones), 141
Sewage effluents, some experiences of, and burning sludge into cement (Granville Cole), 137
Sewage farms, replies to questions issued by the committee, 187, 188
Sewage irrigation in Paris (Sturge), 151
Sewage treatment, ten years' practical experience in, (Hillé), 139
Sewer-gas poisoning, remarks on some of the diseases due to (Brown), 116
Sewers, the ventilation of (Winton), 153
Shannon, sanitary state of the valley of the river, referred to bad regulating weirs (Lynam), 105
Shelford, Mr., *disc.*, 165
Shone, Isaac, pneumatic sewerage system, 144, 182
Shute, Mr., *disc.*, 164
Sillar, Mr., *disc.*, 178
Slagg, Charles, "Suggestions of a State record of the surplus water flowing from high and uncultivated lands," 112
Smyth, John, jun., "On the water supply of the Upper Bann River, Ireland, and the amount of rainfall utilised, 107
South Molton sewage farm, 188
Stansfeld, Right Hon. J. (Chairman), 163, 164, 165, 166, 168, 169, 170, 171, 172, 173, 177, 178, 180, 183, 184
Stoke-upon-Trent sewage farm, 188
Sturge, W. Allen, M.D., "Sewage irrigation in Paris, 151
Suggestions for dividing England and Wales into districts for the supply of pure water, 1-71
Sutcliff, Robert, "Abyssinian tube wells," 113
Symons, G. J., *disc.*, 159, 168
Syson, Dr., *disc.*, 183
Thames and its tributaries (Cresswell), 127
——— Conservancy Board, 189
Thorne, R. Thorne, M D., "The recent outbreak of enteric fever at Caterham," 117, 172
————— *disc.*, 175, 176, 177
Toplis, Frederick, suggestions for dividing England and Wales into water-sheds districts, 3
Tripe, Dr., *disc*, 162, 169, 170, 171, 183

Underground water supply of villages, hamlets, and country parishes of the central and eastern counties of England (Hull), 86

Vacher, Dr., *disc.*, 173, 183

Ward, Dr., *disc.*, 175
Water, methods of securing a sufficient supply of pure, *papers*, 72—116
——— suggestions of a State record of the surplus water flowing from high and uncultivated lands (Slagg), 112
——— supply and storage of pure drinking water, East Brent, Somerset (Denison), 97
Water supply, national, (Prestwich), 93; (Denton), 119
————— of England, on the utilisation of, (Conder), 74
————— of rural districts (Wheeler), 78, 162
————— of large towns (Clutterbuck), 84
—————, connection of the questions of water supply and sewage, *papers*, 116—123
—————, supplement to "Notes on previous inquiries," 189
—————, underground, of the central and eastern counties of England (Hull), 86
Watershed lines, subterranean water-ridges (Lucas), 91, 165
"Wells, Ayssinian tube," (Sutcliffe), 113
West Derby sewage farm, 188
Wheeler, W. H., "The water supply of rural districts," 78, 162
——— *disc.*, 169
Wilson, Dr., *disc.*, 163, 183, 184
Winton, John G., "The ventilation of sewers," 153
Wolstoncroft, Mr., *disc*, 182
Wolverhampton sewage farm, 188
Wrexham, sewage disposal at, (Jones), 151
Wylde, James, *disc.*, 180

Yeld, Dr., *disc.*, 163, 165, 171, 182, 183

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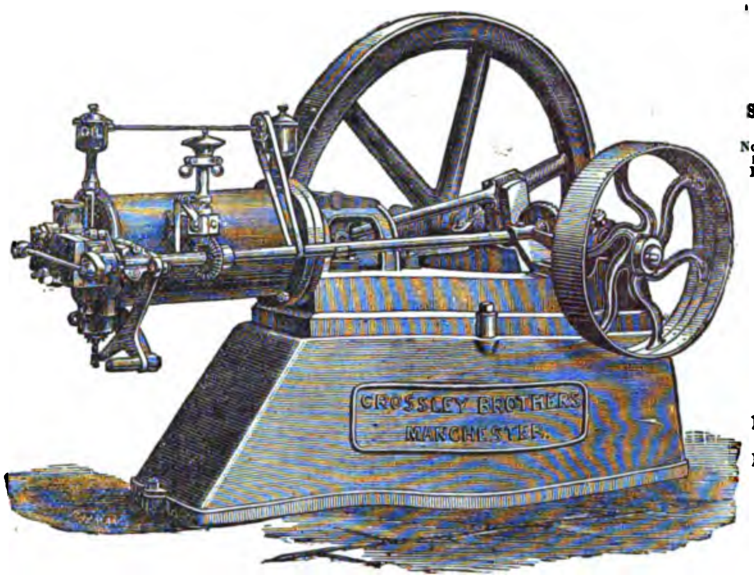

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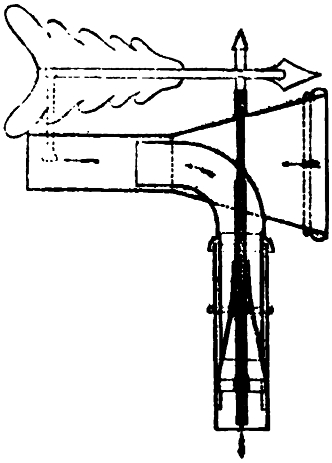

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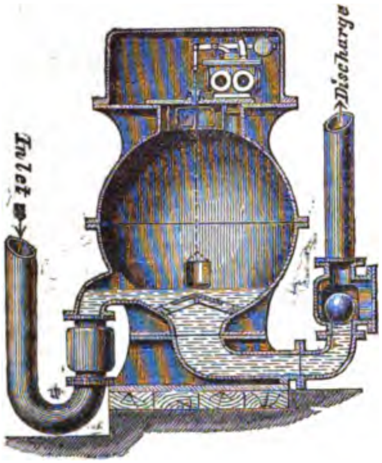

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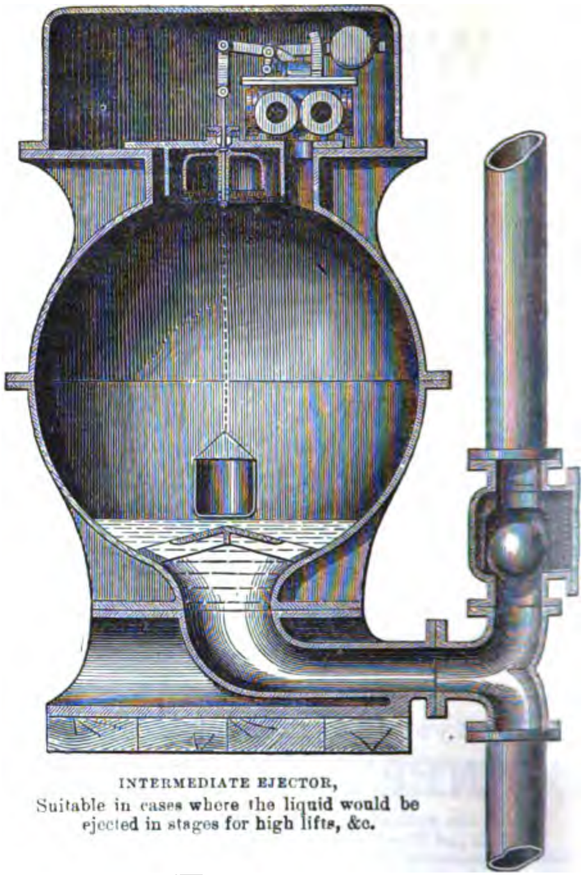

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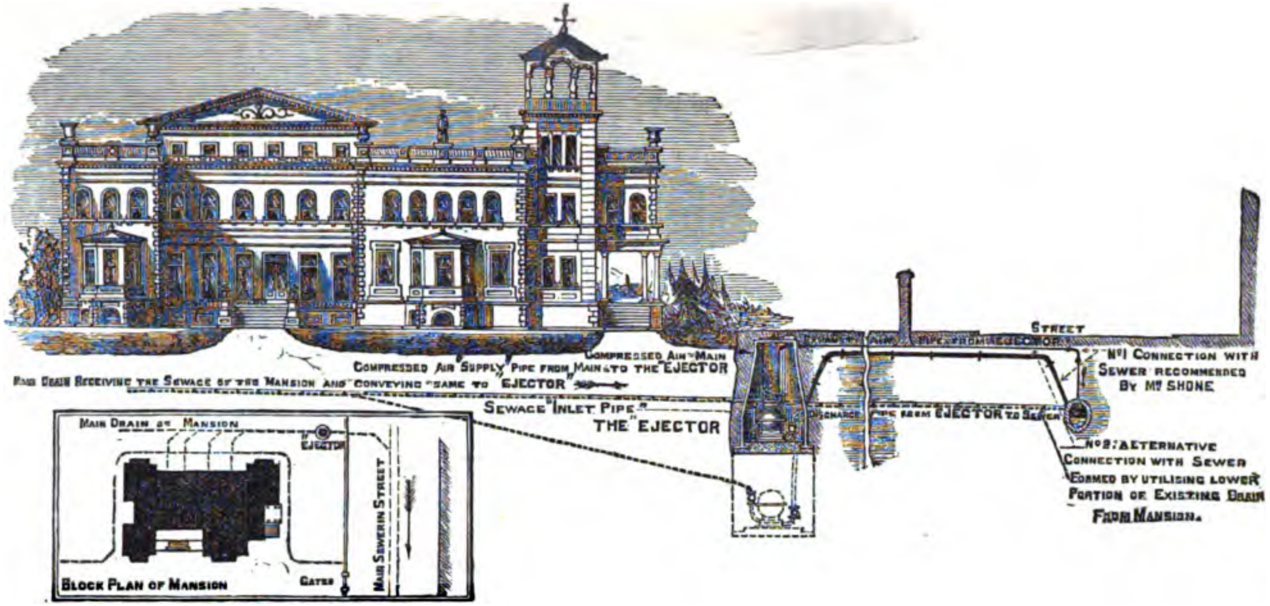

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Compressed Air Main
Sewage "Inlet Pipe"
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Street
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Sanitary Engineer,
18 and 19, Duke-street, Brighton.

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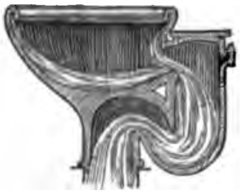

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WHOLESALE DEPOT—8, GOLDEN LANE, LONDON, E.C.

EXPERIENCED WORKMEN TO ALL PARTS.

SEND FOR A PRICE LIST OF

Blake's Self-Acting Hydraulic Rams,

For Raising Water for the Supply of Towns, Villages, Irrigation, Railway Stations, Mansions, Fountains, Farms.

No Cost for Motive Power, which is obtained from the Stream of Water passing through the Rams.

NO OILING OR PACKING REQUIRED.

MADE IN SIZES TO RAISE FROM 300 TO 100,000 GALLONS PER DAY.

This Ram will raise a part of the same water that works it, or will raise pure water from a well or spring, whilst worked from a stream of impure water, and will force to a height of 1,500 feet.

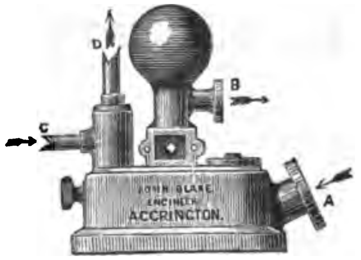

Fig. B.

TESTIMONIALS.

From JOHN TAYLOR, Esq., The Rocks, Bath, August 22, 1878.—"The Self-acting Hydraulic Ram you fixed here in March of last year continues to work well. It has only the same quantity of water and fall to work it as the water-wheel and pump which I used previously to force to a height of 294 feet, and yet the Ram sends up more than double the quantity of water that the wheel did to the same height."

From Captain TOWNSHEND, Wineham, February 10, 1877.—"In answer to your inquiry, I am glad to say the Hydraulic Ram you sent me in November, 1875, is working exceedingly well, and gives no trouble. It will work when quite immersed, as it has been several times during the floods this winter, forcing up water through a delivery pipe 900 yards long at the rate of 80,000 gallons per day, although you only promised 50,000.".

From W. SCARTH, Esq., Agent to His Grace the Duke of Cleveland.—"Raby Castle, Darlington, July 16, 1878.—The Hydraulic Ram you supplied to His Grace the Duke of Cleveland in 1875 is a complete success. It worked for more than two years without once stopping, and throws more water than promised."

From Major STARKIE, Lovely-hall, Blackburn, May 13, 1878.—"Sir,—I have great pleasure in testifying to the good qualities possessed by the Ram you erected here last year. It has done its work well, and not failed as the other Ram did, which was of a different construction and supplied by a different firm. I consider there are great difficulties to contend with here, but your practical mechanical knowledge, both as to the construction of the Ram and its situation here, overcame most of the difficulties that we had to contend against."

Deanwater, Wilmslow, November 20, 1873—"Dear Sir,—In answer to your inquiries respecting the Hydraulic Ram you supplied me with six months ago, I beg to state that I am more than satisfied with it, as it is in perfect order, sending up to the top of the house about 2,000 gallons of water in the 24 hours, whereas you only contracted to deliver in that time 500 gallons. I have, therefore, every reason to be well pleased with your work, and more especially as I had a ram supplied me by another maker which could not send up a single gallon of water to the height required; and a second maker informed me that no ram with a fall of three feet could send up water to the distance required—namely, 120 feet. But yours is an accomplished fact, and does its work most effectually.—Yours, &c. L. HANMER."

From Mr. THOMAS MASON, Alkincoates-hall, Colne, September 30, 1871.—"Sir,—Your Self-acting Hydraulic Ram gives me entire satisfaction; it has been at work about fifteen months, and has only been seen once during the last six months; it is forcing about 1,400 gallons per day of twenty-four hours, to a height of 194 feet."

From JOHN PENNINGTON, Esq., Emmott-hall, near Colne, December 21, 1868—"Sir,—The Self-acting Hydraulic Ram you supplied me with nine months ago continues in excellent condition. It receives water from a spring through a 2 inch pipe, of which it forces 3,600 gallons per day of twenty-four hours to a height of 90 feet, exceeding all you promised, and far surpassing the water-wheel and force-pumps which it has displaced. Its cost is small, it occupies but little space (two square feet), and in mechanical detail is simplicity itself. have much pleasure in recommending it as a cheap and efficient method of raising water."

JOHN BLAKE,

ENGINEER,

ACCRINGTON, LANCASHIRE.

BENRY SHARP, JONES, & CO.,

BOURNE VALLEY POTTERY,

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MANUFACTURERS OF

ROCK-CONCRETE

TUBES

FOR LARGE SEWERS,

MAN-HOLES, CULVERTS, & WELLS;

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TRADE MARK

SILICATED BY THE VICTORIA STONE COMPANY'S PATENT PROCESS.

ALSO OPEN CHANNEL PIPES OF THE SAME SIZES FOR SEWAGE IRRIGATION.

ROCK CONCRETE

These Pipes are of great durability, true in shape, smooth surface, and the action of acids and sewer gases tends rather to harden than to injure them.

☞ BY LAYING WITH CEMENT A WATER-TIGHT JOINT IS AT ONCE EFFECTED.

PORTLAND CEMENT CONCRETE is now recognised as the most suitable material for large Sewers. The advantages claimed for these Rock Concrete Tubes are—

Superiority over brick or Concrete built in situ. The interior surface of the Tubes being of pure Cement and compressed in manufacture, there is not the slightest danger or even possibility of its peeling off.

Economy and Rapidity of Construction. The pipe being laid and jointed, the ground can be filled in quicker than when centreing has to be used.

No risk in the shape of defective or pervious Concrete. While in those cases where extraordinary strength is necessary, it can be supplied in the form of Hydraulic Lime Concrete, or largely diluted Portland Cement Concrete, the tube forming first a centreing, and then a permanent and durable lining for the Sewer.

Facility with which they can be cut, without breaking, for the purpose of joining branch Sewers, &c.

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PURE WATER and WATER ANALYSIS.

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PATENT MOIST COMBUSTION PROCESS,

A REGISTERED SET OF

APPARATUS AND RE-AGENTS.

The Re-Agents are prevared in Professor Wanklyn's Laboratory, and guaranteed by him.

The License for working the process is obtained by purchasing the Set of Apparatus. Price, with instructions, in a lined Mahogany Cabinet, £3 3s.

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FOR TESTING WATER BY THE

AMMONIA PROCESS.

The Solutions are prepared in Professor Wanklyn's Laboratory, and guaranteed by him.

DR. CLARK'S

APPARATUS AND SOLUTIONS,

For working his Patent Process for softening and testing the Hardness of Water.

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AWARDED AT
MANCHESTER AND SALFORD

SANITARY EXHIBITION
AUGUST, 1878,
TO

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IMPROVED PATENT VENTILATOR,

Which can be applied to the Ventilation of every class of Building, Public or Private, Churches, Chapels, Law Courts.

Assembly Rooms, Schools, Prisons, Factories, Kitchens, Stables, &c., and to the Ventilation of Vineries, Conservatories, &c.

Estimates given for the Ventilation of Residences, Churches, Schools, and Public Buildings, on application to

THOMAS LLOYD,
Warming, Ventilating, and Sanitary Engineer,
PATENTEE AND MANUFACTURER, WINCHESTER.

Sole Agent for District for Buchan's Patent Sewer-Gas Tap. South of England Agent for the Vielle Montagne Zinc Works, Belgium.

TESTIMONIALS.

From ERNEST A. DAY, *Architect, Sanitary and Ventilating Engineer, Worcester.*

5, Foregate-street, Worcester, September 27th, 1877.

DEAR SIR,—I have much pleasure in bearing my testimony to the value of your Patent Extract Ventilator. The Ventilator being worked by atmospheric pressure causes a vacuum in the pipe, and thereby draws away the air, smoke, dust, or steam from underneath; its simplicity and peculiar construction prevents down draughts, which are the great and serious inconveniences attending nearly all ceiling or extract ventilators.

Yours faithfully,
ERNEST. A. DAY.

To Mr. Thomas Lloyd, Winchester.

From REV. E. JACOB, *Portsea Vicarage, Kingston, Portsmouth.*

November 6th, 1878.

DEAR SIR,—I think it is only due to you that I should express my entire satisfaction, and the satisfaction I think I may add) of my parishoners with the manner in which you have ventilated the Parish Church of Portsea.

I never officiated in a worse ventilated building than this church in its former state. On Sunday last, though the church was crowded in every part, and there was not even standing room in any one of the passages at the Evening Service, there was no closeness or oppression at all; when the Congregation had left the church, it was hardly possible to believe that some 1,200 had been for two hours in the building, and I need hardly say that on the Monday morning, the air was perfectly fresh and sweet, though previously it had been most disagreeable to enter the church on Monday. If I could use stronger terms of commendation than these I would. You can make any use you like of this letter.

Faithfully yours,
EDGAR JACOB.

Mr. T. Lloyd.

OKES AND ROBINSON'S

PATENT FILTER PRESS

FOR

RAPIDLY AND ECONOMICALLY EXTRACTING MOISTURE FROM THE SEMI-FLUID PRODUCTS

OF

Sewage Precipitation Tanks, Potteries, Sugar Factories, Breweries, Chemical Works, &c.

Particulars as to Cost, &c., can be obtained either at the Manufacturers,

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GROSVENOR ROAD, PIMLICO, S.W.,
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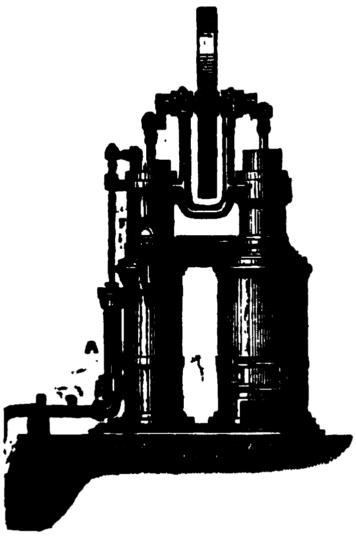
DOMESTIC WATER SUPPLY.

Silver Medal Awarded at the Paris Exhibition, 1878.

RIDER'S PATENT

HOUSEHOLD PUMPING ENGINE



Will raise 500 GALLONS of WATER PER HOUR 80 FEET HIGH WITH A CONSUMPTION of 4lbs. of COKE PER HOUR, or a smaller quantity to a greater height. Requires no skilled labour.

Is PERFECTLY SAFE, it being WORKED by HOT-AIR, and does not affect insurance.

Has NO STEAM BOILER.

Testimonials and full particulars from the Sole Makers,

HAYWARD, TYLER, AND CO.

Can be seen at Work Daily (except Saturday), at

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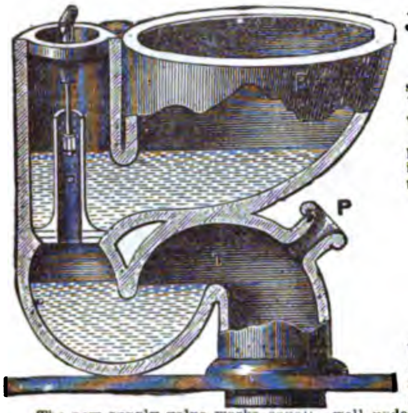
IMPROVED SANITARY AND BUILDING APPLIANCES.

Baths, Lavatories, Water-closets, Household, Scullery, and Slop Sinks, Urinals, Pumps, Sluice Valves, and Water Fittings.



JENNINGS' PATENT VALVE CLOSET AND TRAP.

In One Piece of Earthenware. Over 47,000 in Use.

These Closets are now so widely known that any description is unnecessary. It should, however, be noted that they are now supplied by a New Regulating Surface Valve, suited to any pressure of water, from main or cistern, and closing with a weight, instead of a float, as heretofore used.

The Socket, P, for air-pipe on Trap outlet, is also an addition of great value, preventing the trapping water absorbing and giving off sewer gases into the house; it relieves the hydraulic seal from all pressure, and prevents the syphon action due to a discharge down a contracted soil pipe.

Price, from 70s. upwards. Socket, P, 10s. extra.

JENNINGS' NEW PATENT TRAPLESS VALVE WATER-CLOSET.

In its various qualities Suited for the Cottage or Mansion.

THE CHEAPEST, MOST EFFICIENT, AND COMPACT CLOSET EVER PRODUCED, requires no lead D or other Trap, and therefore cannot become stopped or dangerous to health from a defective syphon. It is provided with solid plug, P, to retain water in basin, a socket, V, for ventilating pipe, and a trapped overflow, T, with connection, W, for lavatory or other waste-pipe.

The new supply valve works equally well under any pressure, and has two deliveries, one to the closet basin and the other into the overflow trap, each time the handle is raised.

Price, from 60s. upwards.

PREVENTION OF WASTE OF WATER.

The above Closets, fitted with Jennings' Improved Patent Arrangement for Prevention of Waste, 25s. extra.

JENNINGS' IMPROVED PATENT SINKS

For Kitchens, Sculleries, Pantries, and Artisans' Dwellings.

A Sink is necessary to every house, and its value is increased by the variety of purposes for which it is adapted. The Improved Sink answers in every respect all the requirements of an ordinary household sink, and also forms an excellent and convenient Tub—for the cook, for the plates, dishes, vegetables, &c.; for the housewife, for her linen; for the butler (lined with pine), for plate, china, and glass; and for the labourer's wife, the additional purposes of a child's bath, or a lavatory for her husband on his return from work.

Price, from 40s. upwards.

JENNINGS' PATENT TIP-UP LAVATORIES.

Those Lavatories are to be found in nearly every Club, Hotel, Bank, Asylum, Union, and other Public Building, and thousands of Private Dwellings in London and the Provinces, and can be made to any dimensions or design. They are to be preferred to basins discharged through plughole, for cleanliness, durability, and simplicity; they leave no filthy deposit on the interior of the basin, and the loss of brass plugs and the breaking of chains are altogether avoided.

Prices, complete, from 63s. per basin and upwards.

JENNINGS' PATENT SLOP SINKS.

For Closets on Bedroom Floors.

Made to suit any position. In Plain or Enamelled Slate.

From £4 4s. upwards.

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GOWER STREET, LONDON, W.C.,

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Mark H. Judge, 6, Dudley-place, W.

The Executive Committee desire to call attention to the increasing need of facilities for obtaining a practical knowledge of Sanitary Appliances and their uses, and of other matters relating to health.

No Institution calculated to supply this want existed in London before the establishment of the Parkes Museum by some of the friends of the late Dr. E. A. Parkes. Although yet quite in its infancy, this Museum contains objects relating to every branch of Hygiene; and it is gratifying to be able to state that Her Majesty the Queen has marked her approval of the undertaking by contributing £50 to the Fund.

The Council of University College, with their usual readiness to recognise an educational want, established a Professorship of Hygiene and Public Health, and have supplemented this by placing at the disposal of the Executive Committee of the Museum, a large room (area 3,500 square feet), in which the collection of Specimens, Models, Apparatus, &c., is temporarily arranged. The Council have also granted the use of a second room for the Library.

The Committee, in order to extend the benefits of the Museum to all classes, have made arrangements to open it to the public.

The Funds at present collected are wholly inadequate for the object in view, and a very much larger sum is required to make the Museum a great Central Institution for the instruction of the public. The Executive Committee, therefore, confidently appeal for pecuniary support to all those who are interested in Technical Education and Sanitary Science.

Subscriptions may be paid to the Treasurer, Professor Berkeley Hill, 55, Wimpole-street, W. Cheques and Post-office Orders to be crossed "Union Bank." All communications relating to the presentation of articles to the Museum, should be addressed to the Curator, Mr. Mark H. Judge.

University College, London,
May, 1879.

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GAS, STEAM, HOT WATER,
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HYDRAULIC ENGINEER.
COOKING APPARATUS AND BATH WORK
OF EVERY DESCRIPTION.
PNEUMATIC AND ELECTRIC BELLS.
Speaking Tubes, Wind Vanes and Lightning Conductors of the most Improved kind.

PATENTEE OF A
SELF-FLUSHING AND WASTE-PREVENTING WATER CLOSET,
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This Association has been formed for the purpose of relieving the Sanitary Authorities of Towns of the trouble attending sewage disposal and purification, in accordance with the requirements of the Rivers' Pollution Prevention Act. The Association is prepared to undertake, for an annual subsidy, all the operations incident to sewage purification, either by chemicals or by land irrigation, or by a combination of the two. The Association's chemical process is in successful operation at Coventry and Hertford, and is open to inspection at any time without order.

Information can be obtained by application to the Managing Director.

THE PATENT

"WASH OUT" CLOSET.

The difference between this Closet and others with water in the bottom receive the soil, is that in them you depend upon the water *floating* the soil paper out of the basin, or have a *discharge valve or plug* placed between basin and the trap to retain the water in the basin. The objection to the mer is that the soil, &c., is frequently left in the basin, and to the ter that the soil adheres to the valve, stopping its proper working, and pregnating the water in the basin. By the "**Wash out**" arrangement h these evils are avoided. The water is so directed in entering the basin t it makes at once for the outlet, **driving** before it the soil and paper out the basin and through the trap, leaving pure water to fill the basin. There no metal or valves of any kind exposed to the action of the soil. It is portant to have an 1¼-inch service pipe. It can be fixed in the place of any inary closet. This Closet is designed to meet the requirements of the two lons service.

The ventilation of the traps for these Closets is also provided for (*when rdered*), by a pipe of 2¼ inches diameter; this opening can also be used as neans of unstopping the trap should it ever need it. The trap is made to fully one inch, and thus an efficient trap is secured.

Extract from the *Architect* of June 9th, 1877, page 373. "How to in a House," from a paper by T. Mellard Reade, Esq, C.E., read before Liverpool Architectural Society:—

> "I consider the pan-closet objectionable, especially since the compulsory introduction of the two-gallon regulating cistern has increased the difficulty of getting the after flush to fill the pan. The 'Container' is usually a reservoir coated with filth, hidden by the pan holding the water in the basin. A basin with a trap at the side or back, called a '**Wash out**' basin, is a far better apparatus."

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Crescent Foundry, Cripplegate, London, E.C., and The Foundry and Works, Walton-on-the-Naze, Essex,

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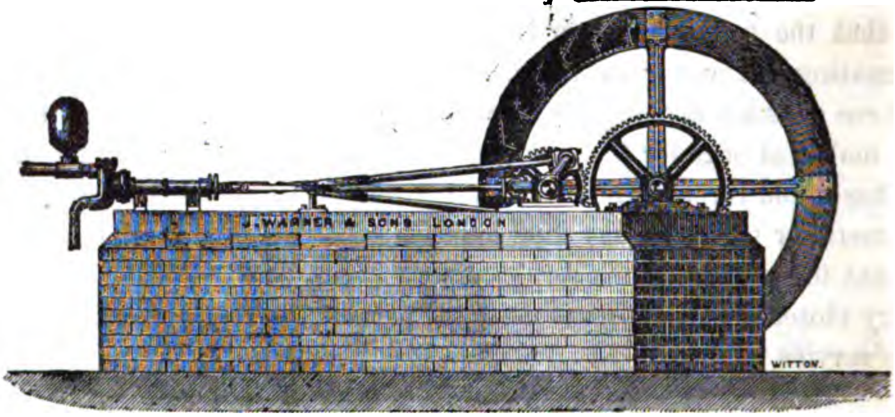

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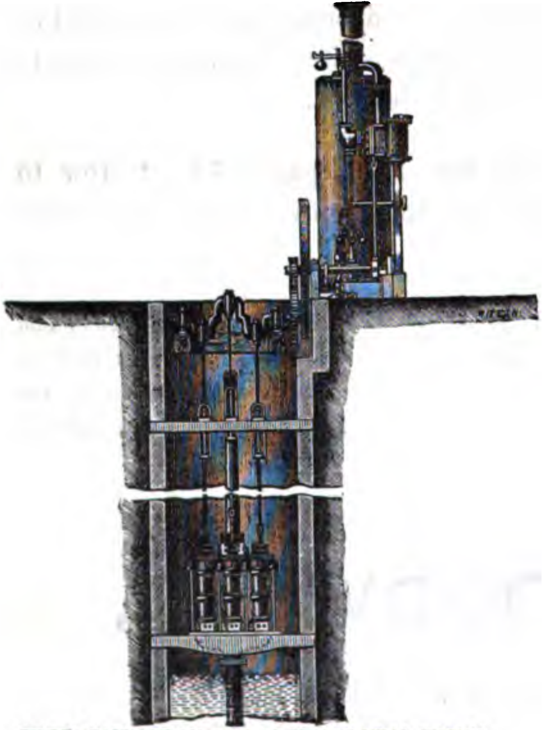

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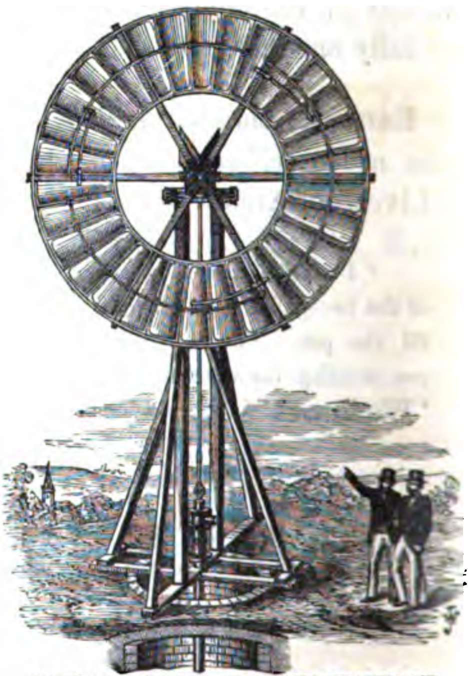

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HIGH-PRESSURE FILTER.

This Filter is constructed on entirely new principles, is of extreme simplicity, easily managed and cleansed, well adapted for household purposes, as well as for every kind of filtration, especially for all liquids and semi-liquids, including **Beer, Wine, Cider, Oil, Varnish, &c.,** also for use in **Cement, Pottery, and Sewage Works, Breweries, Distilleries, and Sugar Refineries.**

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MR. LEWIS OLRICK, 27, Leadenhall Street, E.C.

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DISINFECTANT & ANTISEPTIC.

"SANITAS" consists of the aerial oxidation products of the oils generated naturally in Pine and Eucalyptus Trees. "SANITAS" is singular in being the ONLY KNOWN PREPARATION which is at once an ANTISEPTIC, DISINFECTANT, and DEODORISER. At the same time it is not merely NON-POISONOUS, but is HEALTHFUL in itself.

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For List of Articles, their prices and uses, apply to the

"SANITAS" CO., LIMITED,

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THE

Silvertown Electrical Water-Level Indicator.

SOLE MANUFACTURERS:—

The India Rubber, Gutta Percha, and Telegraph Works Company (Limited).

For showing the actual height of the Water Level, in feet or inches, in reservoirs, tanks rivers, tideways, &c., &c., at no matter what distance from the water the instrument may be placed.

The Instrument is perfectly trustworthy, and not at all liable to get out of order, requiring no attention when once put up.

The following letter has been received from MESSRS. H. YOUNG & Co., *the Contractors for the erection of the New Waterworks at Leamington :—*

Hayle Foundry, Nine Elms,
London, S.W., 22nd April, 1879.

GENTLEMEN,—We have pleasure in stating that the Electric Indicator at Leamington continues to work in every way satisfactorily.

We know of no apparatus so admirably suited for indicating rise and fall of water in reservoirs at a distance. There is nothing likely to get out of order or require attention. Thanking you for working out the idea so well,

We are, yours faithfully,
H. YOUNG & CO.
(GEO. ROBERTSON.)

The India Rubber, Gutta Percha,
and Telegraph Works Company,
100, Cannon-street, London, E.C.

Estimates for the supply and erection of this Apparatus will be furnished on application at the Company's Office, 106, CANNON-STREET, LONDON, where further particulars may be obtained.

JOHNSON'S

PATENT

HYDRAULIC FILTERS,

FOR THE

TREATMENT OF SEWAGE SLUDGE ON THE PNEUMATIC SYSTEM.

Where large quantities of material have to be dealt with, this System will be found the simplest known means of drying Sludge or Pail Emptyings without fuel. It is also the lowest in cost of installation and working expenses. The Sludge is hermetically closed when the Apparatus is at work, and is consequently worked without smell.

For Plans, Prices, and other particulars, Address

JOHNSON'S ENGINEERING WORKS,
CARPENTER'S ROAD, STRATFORD, E.

BOYLE'S PATENT
SELF-ACTING
AIR-PUMP VENTILATORS

Effectually Extract the Foul Air; have no mechanical movement; are entirely free from down-draught; and can be constructed to harmonise with every style of Architecture.

They are pronounced by the highest authorities to be the most efficient Ventilators yet invented.

Soil-Pipe Ventilator (specially made), 10 in. diameter, 3-in. Pipe, 35s.

"Boyle's Patent Self-Acting Air-Pump Ventilator, which does not revolve, is the best Soil-pipe Ventilator that I know of."—Ernest Taylor, Esq., F.R.I.B.A.

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VENTILATING & SANITARY ENGINEERS,
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GLASGOW. LONDON.

"Since these excellent Ventilators have been introduced we have now got perfect methods of Ventilation."—Dr. B. W. Richardson, F.R.S.

TESTIMONIALS.

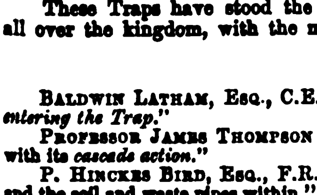
From the late Sir Gilbert Scott, Architect.
"I have used your Patent Self-Acting Air-Pump Ventilators with complete success.
"From experience of them in my own house and other buildings—public and private—where they have been applied under my direction, I can confidently and will always have great pleasure in recommending them."

From Arthur Cates, Esq., F.R.I.B.A., Architect to the Crown, &c.
"I have used your Air-Pump Ventilator with satisfactory result. Those fixed under my direction at the Library of the Inner Temple have realised my expectations, and completely fulfil the object which I had in view. I consider this application of them a severe test, and the success which has attended it confirms the statements which you make as to their efficacy."

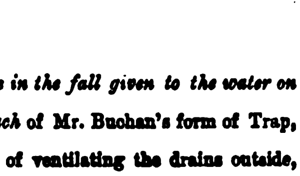
From Sir William Thomson, F.R.S.
"I have seen several different forms of Mr. Boyle's Air-Pump Ventilator in actual operation, and have much pleasure in testifying to their efficiency. They thoroughly realise the favourable anticipations which I formed from experiments on models shown to me by Mr. Boyle. Having one fitted up in my yacht, I find it has caused a very decided improvement in the draught."

HEALTHY HOUSES
SECURED BY USING
BUCHAN'S PATENT VENTILATING DRAIN TRAPS.

No. 1.—Buchan's Trap.



No. 2.—Buchan's Trap.



These appliances provide in a simple, cheap, and yet efficient manner, for the Ventilation of the Drains or Pipes on the side of the Trap nearest the house, and, at the same time, lock off the sewer or other bad gases, and prevent their entrance to the house. The sizes in general use are 4, 6, and 9 inches. Style No. 2, as per diagram, has access opening upon the outer side of the Trap, which is of advantage when jointing, and may be utilised to ventilate the sewer or the drain beyond the Trap, when wished; and is always useful for easy examination of the drain.

The vertical drop of the water on entering the Trap is a peculiar feature, and tends to keep the Trap clean.

These Traps have stood the test of several years, and are now in use to the extent of some thousands all over the kingdom, with the most satisfactory results.

TESTIMONIALS.

Baldwin Latham, Esq., C.E.—"The *advantage* of Mr. Buchan's Trap *consists in the fall given to the water on entering the Trap.*"

Professor James Thompson (of Glasgow University).—"*I approve very much* of Mr. Buchan's form of Trap, with its *cascade action.*"

P. Hinckes Bird, Esq., F.R.C.S.—"I find it *a very cheap* and *efficient* means of ventilating the drains outside, and the soil and waste pipes within."

Kenneth M. Macleod, Esq. (Sanitary Inspector for Glasgow).—"There can be *no doubt of its value*, as a sanitary appliance."

G. R. Andrews, Esq. (Surveyor to Commissioners, Bournemouth).—"Your Trap appears to me to be *just the thing suitable for our Bye-laws.*"

Sole Makers:—J. & M. CRAIG, FIRE CLAY MANUFACTURERS, Kilmarnock, Scotland.
Makers also of White Enamelled Sinks, Washing Tubs, Bricks, &c.
Stocks of Traps and Fittings, kept in principal Towns in the United Kingdom.
London Agent:—MR. ROBERT GALT, 110, CANNON STREET, E.C.
Price Lists and Particulars on Application.

OXYCHLOROGENE,

A Powerful and Complete Deodoriser, Antiseptic, and Disinfectant.

This Fluid is prepared strictly in accordance with the most recent researches in Chemical Science, and is practically the most perfect Disinfectant and Deodoriser ever introduced. It is entirely free from anything of a poisonous nature, and may be used with the greatest confidence either in the sick chamber or for the destruction of infectious germs, offensive odours, or impurity of any kind. It has no unpleasant odour, and when diluted does not stain, therefore may be freely used without the least fear of injury in its application.

May be obtained of all Chemists and Medicine Vendors in the Kingdom. In Bottles at 1s. and 2s. 6d. each, and in Bulk at 8s. per Gallon, with full directions for use.

PATENT POTASH SOAP,

For use in Cold or Lukewarm Water. One 1 lb. is equal to 2 lbs. of best yellow soap.

It is the Best and Cheapest Soap for Laundry Purposes. It is warranted not to injure the most delicate material. The PATENT POTASH SOAP possesses cleansing properties far in advance of any other soap, and by the new process of washing in cold water, according to the directions given, the dirt is dissolved and discharged from the fabric with very little rubbing, while the clothes are thoroughly cleansed and rendered pure and white at much less cost, and in half the time of the usual process of washing. The annoyance of steam is avoided, the clothes are not worn or torn, and no soda, washing, or bleaching powder being used, they are not injured or destroyed. One trial will lead every household to abolish the old and destructive system of washing. The PATENT POTASH SOAP acts admirably in any description of washing machine.

Of all Grocers and Oilmen, in Bars, 6d. per lb., or 1 cwt. Boxes 52s.

PATENTEES AND SOLE MANUFACTURERS—

MACKEY, SELLERS, AND CO.,

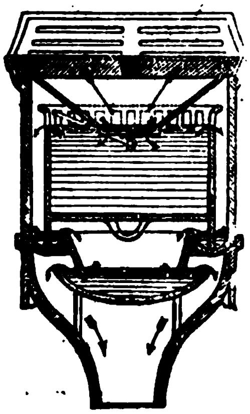
WHOLESALE MANUFACTURING CHEMISTS,

1 and 2, BOUVERIE STREET, FLEET STREET, LONDON.

DANIEL CLARK,

WATERLOO FOUNDRY, CARLISLE.

PATENTEE AND MANUFACTURER OF



Patent Stench Trapped Gullies; Lathams's Patent Sewer Ventilators; Young's Improved Ball Valves, combined with Clark's Patent Gullies, for preventing the Flooding of Streets or Cellars; Penstocks; Flushing Gates; Tidal or Flap-Valves; Sluice Valves; Side-Entrance Safety Grating; Combined Manholes and Ventilating Grates; Charcoal Baskets, &c., &c.

Drawing and Prices of which will be forwarded on application.

Chemical Apparatus. Scientific Instruments.

We wish to recommend our LARGE STOCK of every description of

PORCELAIN, GLASS, STONE, & METAL APPARATUS,

For Chemical and Philosophical Purposes and Lectures.

ELECTRICAL, MEDICAL, & EXPERIMENTAL COILS & APPARATUS.

Bunsen's Modified Filter Pumps, from 10s. 8d. to 67s.

ELECTRICAL BATTERIES AND ELEMENTS.

CAILLETET'S APPARATUS FOR LIQUEFACTION OF GASES.

Catalogues and Illustrations on application. A Liberal Discount allowed to Wholesale Buyers.

Sets of Apparatus according to Professor Valentin's "Book of Chemistry," Professor Attfield's "Manual of Chemistry," &c., always in stock.

WHOLESALE IMPORTERS & MAUFACTURERS,

AUG. BEL & Co.,

CONTRACTORS TO THE GOVERNMENT,

34, Maiden Lane, Southampton St.,

STRAND, W.C.

Sets of Apparatus as required by the Government Schools always ready and kept in stock.

For the convenience of Teachers and Students at the South Kensington Classes, the Science and Art Department has authorised us to keep a Stock in the store-room, first floor of the building, where the different sets and other articles are always ready for delivery.

Price 1*s.* 6*d.*, *by post* 1*s.* 8*d.*

NATIONAL WATER SUPPLY.

NOTES ON PREVIOUS INQUIRIES,

PREPARED IN CONNEXION WITH THE

CONGRESS, 1878.

Being an outline retrospect of the previous inquiries and recommendations respecting Water Supply.

"The literature of the subject, in its various branches, is very extensive; so that to keep the retrospect within such limits as are convenient for easy reference, it has been judged desirable that it should, as far as possible, take the form of a key to what has been done. As it is believed that few public libraries possess the works of reference through which previously acquired information is distributed, it has been thought useful to print in full some extracts from official books known to be out of print. These extracts are, for the most part, confined to questions which are of importance to all districts, applying to general principles on which a supply must be rejected or admitted."

NOTICE.

A few copies of the Reports of the Conference on Health and Sewage of Towns, held in the years 1876, 1877, and 1878, are still in print, and may be obtained on application to the Secretary of the Society of Arts. Price 2s. each.

IMPROVED

PATENT "DUPLEX" L

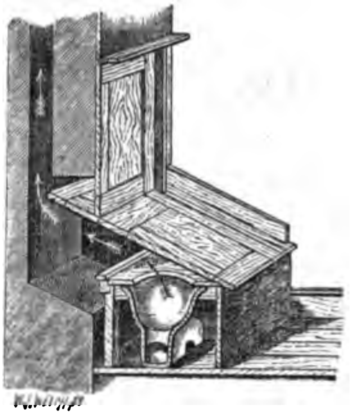
AND AUTOMATIC FLUSHER,

Adapted to Water-closets, Housemaids' Sinks, Lavatories, Urin

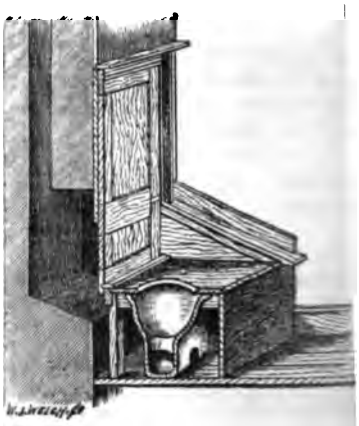
MANUFACTURED BY

E. HOWARD,

1A, UPPER BAKER-STREET, LONDON, N



Lid of W.C. down, and when
Apparatus is not in use.



Lid of W.C. raised, and when
Apparatus is in use.

It has hitherto been found practically impossible to prevent the emission of foul
from waste or soil pipes of water-closets, sinks, wash-basins, &c., especially when these
as they almost always necessarily must be, are connected with the drains. The object
invention is to carry off all such noxious gases into the open air, and so prevent them en
the apartment in which the apparatus is placed.

The lids or covers to the water-closets, sinks, or basins are so constructed that whe
down they are open to the flues above described, and any offensive gases rising throug
soil or waste pipes, or escaping from flaws in the joints thereof, are carried upwards and
to the outer air instead of entering the room.

Moreover, the water-closet lids are so contrived that the action of shutting them
empties and flushes the apparatus, similarly to the action resulting from pulling up the
in the ordinary manner, and consequently the upward rush of foul gas from the soil pip
always attends this operation is rendered harmless by being conveyed by the ventilating
the outer air.

It will readily be seen that, by the adoption of this principle, the rooms containin
apparatus are, while not in use, rendered to all intents and purposes external buildings.

A full-sized model of the apparatus may be seen at the Parkes' Museum of Hygiene,
versity College, Gower-street, and at the Manufacturer's, 1A, Upper Baker-street, N.W.;
Manufacturer would be happy to call on Architects and others with a model of the app
showing its working.

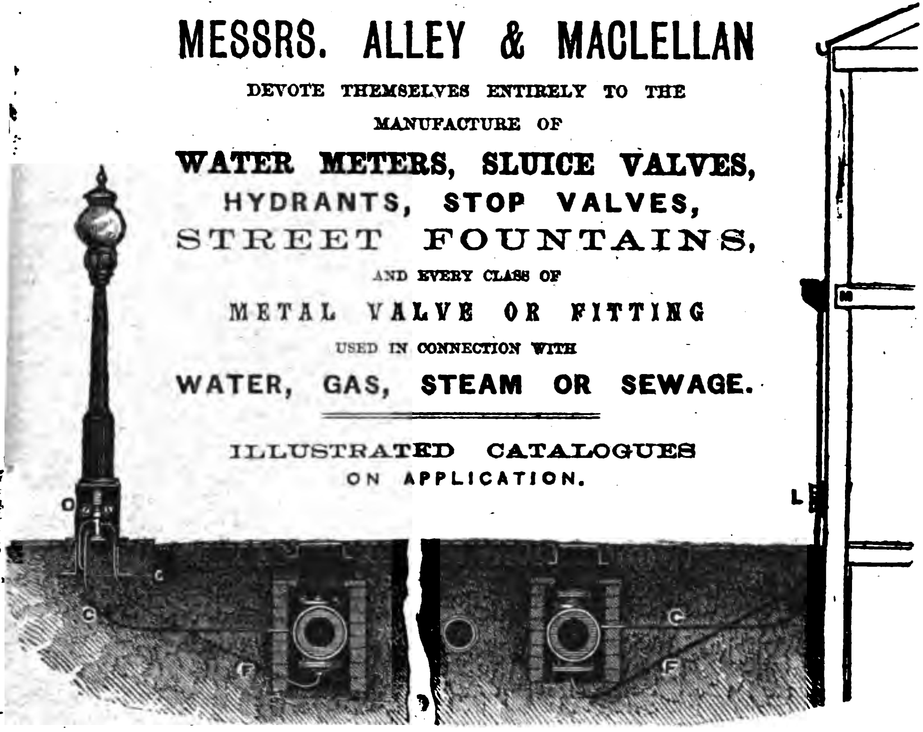
Some hundreds of the Duplex Lids may also be seen in use at the Metropolitan Conval
Institution, Norbiton; the Clerkenwell Mortuary; Spa-fields Burying-ground; St. Ge
Union Infirmary, Fulham-road; St. Marylebone Workhouse, Marylebone-road; St. O
Union Infirmary, Deptford Lower-road, Rotherhithe; Holborn Union Infirmary, Arc
road, Upper Holloway; and other public and private buildings.

The whole of the woodwork is made of the best selected pitch pine and teak, but mah
or any other material can be used if desired.

FOULIS'
TENT WATER GOVERNOR.

MESSRS. ALLEY & MACLELLAN
DEVOTE THEMSELVES ENTIRELY TO THE
MANUFACTURE OF
WATER METERS, SLUICE VALVES,
HYDRANTS, STOP VALVES,
STREET FOUNTAINS,
AND EVERY CLASS OF
METAL VALVE OR FITTING
USED IN CONNECTION WITH
WATER, GAS, STEAM OR SEWAGE.

ILLUSTRATED CATALOGUES
ON APPLICATION.



ADVANTAGES.

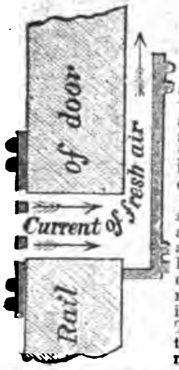
st.—It maintains a constant outlet pressure, with a varying inlet pressure and outlet
mption.
2nd.—The outlet pressure can be reduced to any pressure below that on the inlet simply
tting off the weights O.
3rd.—By reducing the pressure the fittings are saved from injury.
4th.—By equalising the pressure at various levels in district, every person gets a fair
ly of water, while waste is *prevented*.

---

one case where this Governor is at work, the saving affected is Thirty per Cent. of the previous consumption.

Engineers can have full particulars on Application to the
SOLE MAKERS—
ALLEY AND MACLELLAN,
ENTINEL WORKS, GLASGOW.

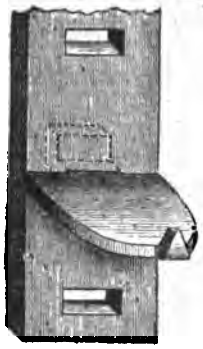
CURRALL'S PATENT VENTILATO



VENTILATION WITHOUT DRAUGHT.

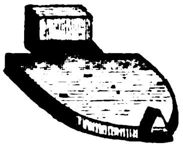
Efficient ventilation is produced naturally by a refreshing atmosphere clearing away one th
and oppressive, and this natural ventilation is needed when the doors and windows are d
ventilation of rooms, too much attention has generally been given to Outlets, and not suffi
attached to Inlets, and especially to their relative positions; there usually being an outlet in the r
at the lower part—the fireplace, but only a deficient inlet by draughts from badly-fitting doors an
yet the stoppage of those chilling draughts (unless an inlet were otherwise made would) no
the escape of the vitiated air, but would bring the smoke from the fire into the room instead of
chimney.

For efficient ventilation without draughts, and easily applied, Mr. Currall brings forward a
simple form of Inlet Ventilator; the inlet being *much more important than the outlet*, as unless fresh
admitted, vitiated air cannot be removed. The Inlet is generally fixed at the lower part of the r
about three or four feet from the floor; for the admission of fresh air, a long aperture (or a series of
line) is made through one of the rails of the door, or the bottom rail of the window sash, or throu
over this aperture on the inside of the room is screwed Currall's Patent Inlet Ventilator. It
metal plate, and (when fixed) is open only at the top side, through which, without any draught
incoming current of fresh air rapidly ascends directly towards the top of the room, where it gradu
This necessary supply of fresh air also provides for the requirements of the fire, and keeping the
the chimney steadily upwards, becomes a remedy for the nuisance of a smoky chimney. A peri
may be fixed over the aperture on the outside.



PATENT BOOK-SHELF FITTINGS.

These Fittings are specially adapted for the Shelves of BOOK-CASES or other shelves, the
of which has, from time to time, to be varied to suit the varying requirements of a library. A
method hitherto generally adopted for such shelves is to support them at each end by two stud
of which are mortised into the shelf, and the pins driven or otherwise fitted into holes two or m
apart bored in two rows into the upright frames; these holes are very seldom accurately fitted t
and even where so done in the first instance, from the shrinking or expansion of the wood,
become too large or too small for the pins, and the alteration of the adjustment of a shelf is
rendered an extremely troublesome operation. The Patent Fittings remedy this, and save
and trouble; in place of the rows of holes so far apart, metal strips perforated at intervals
quarters of an inch for the reception of the very simple but strong metal plates, which take th
the old studs, are mortised in and screwed to the frames. The insertion, at the required interval
plates into the perforations in these strips is made instantaneously, consequently the position of
be easily altered without an irritating expense of trouble, and waste of time. The thinness of
renders any mortising in the shelf unnecessary, and the small intervals between the perforati
strips enables the whole space occupied by the shelves to be used most economically. These fitti
used with a shelf sufficiently strong itself to bear the weight, will support without strain more th
a ton.



HOOKHAM'S PATENT

STEEL PIANO-WIRE PICTURE-LINE.

PERFECT SECURITY, WITH EXTREME FACILITY IN HANGING.

The LINE is made with a core of STEEL PIANO WIRE of the quality used in the best pianos, being th
adapted to support a great strain for almost any length of time. Exactly what is required for pictures. T
protected from rust by a binding of waterproofed cotton; over this is a covering of silver plated or ormolu wire,
being well lacquered, will keep its colour.

THE PATENT FASTENERS are an entirely new feature, and will be found an immense convenience. A
can be hung in a third of the time, and adjusted easily to an eighth of an inch. Every one who buys the lin
ask for the Fasteners. They make picture-hanging a pleasant amusement instead of a trouble. Their co
trifling, and they effect an economy of the line.

The line is sold on Registered Reels, which will be found very convenient in use.

Registered Nippers, made entirely of cast steel, and useful for numerous household purposes, especially for op
champagne, may be had with the line.

⁂ The various articles may be procured through any Ironmonger.
Wholesale of

WILLIAM TONKS AND SONS

Moseley Street, Birmingham,

FROM WHOM ILLUSTRATIONS AND PARTICULARS MAY BE OBTAINED.